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WORKING MATERIAL-CONTRIBUTED PAPERS

PART I

Papers 001-060

DIAGNOSTIC RADIATION OF POTENTIALLY REPRODUCTIVE FEMALES

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ABSTRACT

Objectives: To find out how consistent or variable is the understanding and practice of radiation protection procedures for women in the childbearing age at a multispecialty tertiary hospital. **Setting:** Riyadh Military Hospital Study. **Design:** Non-clustered population survey. **Methods:** A questionnaire was distributed during grand rounds, mid-day clinics and a radiology conference. Questions included which radiation protection rule does the respondent use for females, whether he or she is familiar with those rules and what is his or her source of reference. Further questions were about the radiation dangers to the fetus. **Results:** Response was 95 (100%). Fifty-seven (60%) were males and 38 (40%) were females. The majority 50 (53%) were Saudis, 16 (17%) Western and 29 (30%) were other nationals. Sixty-two (65%) followed the old rule "10-day rule"; 17 (18%) followed the new "28-day rule" and 16 (17%) didn't know which rule to follow. None of those who followed the "28-day rule" indicated hospital policy as their reference. **Conclusions:** The understanding and practice of radiation protection guidelines for females is inconsistent. There is significant unfamiliarity with the radiation protection rules among our hospital practitioners.

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Keywords: *Radiation protection, fetal irradiation, reproductive females.*

There has been significant changes in the guidelines concerning the exposure of women in the child bearing age to diagnostic radiation.[1,2,3] The 10-day rule states that all radiologic examinations of the lower abdomen and pelvis of women of reproductive capacity, that are not of importance in connection with the immediate illness of the patient, be limited in time to the period when pregnancy is improbable, i.e. the 10-day interval following the onset of menstruation. This was replaced by the 28-day rule, which states that the risk of irradiating a fetus is too small in the first month following the start of menstruation and no limitation is necessary unless a period is missed. Lately there has been a recommendation of limited return to the 10-day rule[3] for procedures delivering high radiation dose to the female pelvis, namely pelvic computerized tomography (CT) and barium enemas.

From our own observation, many questions on safety and timing do arise when performing or deciding appointments for radiological procedures in females. The objective of this study is to find out how consistent or variable is the understanding and practice of diagnostic radiation for potentially reproductive females among our hospital practitioners.

Methods A non-clustered population survey. A questionnaire was distributed during grand surgical and medical rounds, a radiology conference and mid-day primary care/dental clinics. Some of the meetings were attended by personnel from other institutions in Riyadh. These were excluded from this study. Demographic information was collected. Respondents were asked whether they followed the 10-day rule or the 28-day rule and whether they were familiar with either of them. They were also asked about their source of information regarding these rules whether it was from the hospital policy, a book, a lecture, course or their own guess. Further questions covered what the respondent would consider is the most dangerous period for fetal

exposure to diagnostic radiation and what are the specific dangers. The questionnaire was initially pilot tested. In a study in Britain[4] 20% of hospitals followed the old guidelines. This was used as an acceptable risk with an allowance up to 35% for maximum tolerable prevalence to calculate the sample size for a statistical power of 99.9%. results were manually checked for completeness and were subsequently entered on a data base file. Epistat statistical package was used for analysis and chi-square test for cross tabulation.

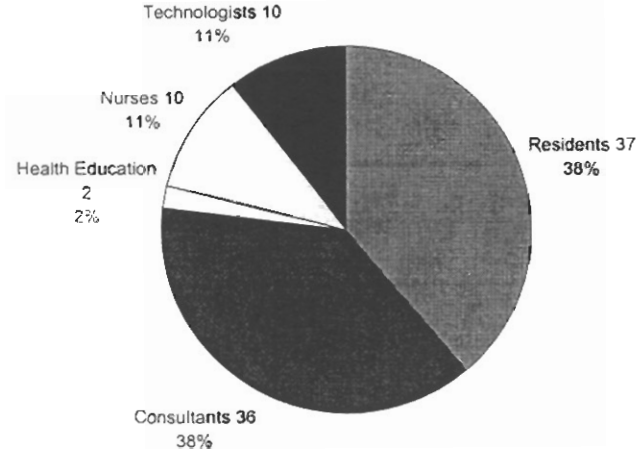

Figure 1a – Actual jobs of respondents

Results There were 95 respondents (100% of this cohort. Fifty-seven (60% were males and 38 (40%) were females. The majority 50 (53%) were Saudis, 16 (17%) were Western and 29 (30%) were other nationalities. The actual jobs and departments are shown in Figures 1(a) and 1(b).

Sixty-two (65%) indicated that they follow the 10-day rules; 17 (18%) followed the 28-day rule while 16 (17%) didn't know which rule to follow. Of those who followed the 28-day rule 12 (70%) were Saudis, 2 (12%) were Western and 3 (18%) were other nationals. Thirty-seven (39%) respondents said they were not familiar with the 10-day rule and 66 (69%) were not familiar with the 28-day rule.

None of those who followed the 28-day rule indicated that hospital policy was their source of information. The selected definition for the childbearing age is shown in Figure 2. Only 2 (2%) of the respondents emphasized mental retardation as the potential radiation hazard to the fetus2.

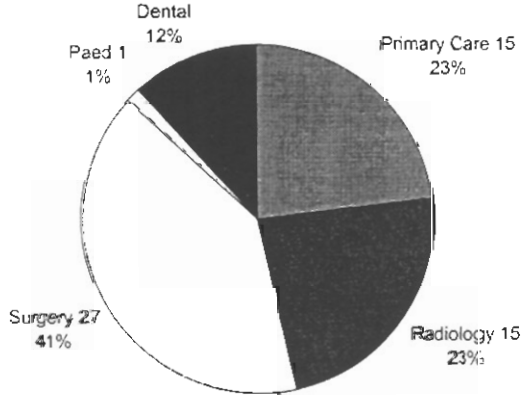

Figure 1b – Departments of respondents 1

Discussion Radiation protection is an important aspect of patient care. The number of radiological examinations is increasing. As many as 20% of x-rays are not necessary.[5] From our records, females representation (40%) of those undergoing radiological procedures in our department. It is not uncommon that a radiological examination for an adult female may be denied, rescheduled or canceled because or radiation protection guidelines.[4] This may cause frustration.

The majority 62 (65%) of our hospital staff involved in this study followed the old guidelines. This is a very high proportion compared to a study in Britain.[4] However our study was for individuals within one hospital unlike the study which compared policies in different hospital.[4]

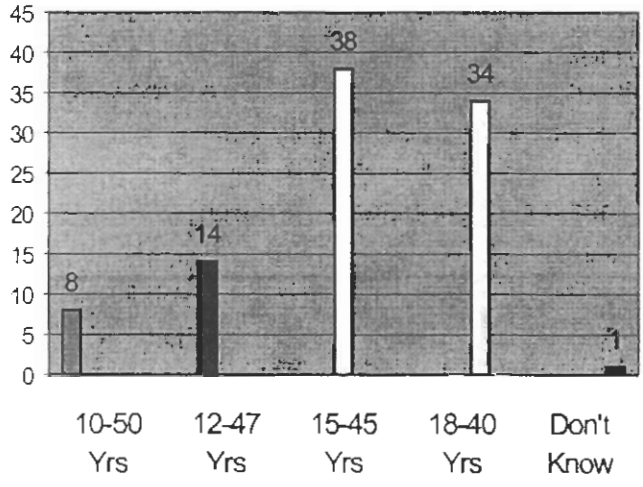

Figure 2 – Child bearing age n = 95

Our hospital is multinationally staffed. In absence of strict adherence to hospital policy their response can give reflections of practices abroad or a prejudiced assumption for the practice in Kingdom.

Twenty years ago marital age in Saudi women was low.[6] The rate of first marriage under 15 years of age was 33%. This has dropped to 3.5% but 15.4% of females between 15-19 years are married. About one third of our respondents believed that the child bearing age is only 18-40. This is an underestimate. Only 35 (37%) of respondents correctly identified the period with highest radiation risk to the fetus in utero (8^{th} – 15^{th} week). Accurate identification of this risky period was the main reason which prompted changes of the rules.[2] Only 2 (2%) mentioned mental retardation as a possible risk. In fact this is the main potential danger.

Conclusion The understanding and practice of radiation protection guidelines for women in childbearing age is inconsistent among our practitioners. There is unfamiliarity with the guidelines. Training and education of personnel is necessary. Review and/or circulation of hospital policies is recommended.

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USING THE BERT CONCEPT TO PROMOTE PUBLIC UNDERSTANDING OF RADIATION

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Abstract
Radiation phobia can be greatly decreased if the simple BERT (Background Equivalent Radiation Time) concept is used to explain the dose to all diagnostic radiology patients. It converts the radiation dose to an equivalent period of natural background radiation. It is understandable, it does not mention risk, and it educates the patient that human-made radiation is the same as the background radiation which gives them most of their annual dose. Medical physicists should provide each clinical x-ray unit with a table that gives the BERT value for various procedures and patient sizes and educate the radiologists and radiographers how to use the BERT approach for relieving radiation anxiety.

1. Introduction

An occasional patient will ask: "Are x-rays safe?" or "How much radiation did I receive from my chest x-ray?" Medical physicists have a responsibility to instruct radiographers and radiologists how to give a reasonably honest and understandable answer to the patient. They can certainly explain that diagnostic x-rays are safe. There are no data to indicate otherwise. The question about the amount of radiation to the patient is difficult to answer in an understandable way. First, because it is a rare x-ray unit that has a meter to measure the radiation delivered to the patient and second, because scientific units for radiation dose are not understood by the patient.

2. Explain radiation dose to a patient using the BERT concept

Answering the patient's question about the amount of radiation would be easy if you knew the effective dose. However, it is unlikely the patient would be satisfied if your answer is "Your x-ray dose is about 1.1 mSv." The patient would understand and be satisfied if you explained that the dose is about equal to six months of natural background radiation, assuming the average background rate in the U.K. is about 2.2 mSv per year. Background radiation varies greatly over the earth. The explanation need not use the local background value since there is usually a large uncertainty about the effective dose which depends on biological constants which cannot be determined. The purpose is not to provide high scientific accuracy but to relieve anxiety about radiation by giving an understandable and reasonably correct answer.

This concept of explaining radiation is called the Background Equivalent Radiation Time or BERT. [1,2] The effective dose from an x-ray examination to the patient is converted to the time (in days, weeks, months or years) to obtain the same effective dose from background radiation. This method is also recommended by the U.S. National Council for Radiation Protection and Measurement (NCRP). [3] The BERT method has several advantages: (i). It is understandable to the patient, (ii). It does not mention radiation risk which is unknown, and (iii). It educates the patient that he or she lives in a sea of natural or background radiation.

3. Radiologists and radiographers should educate patients about background radiation

Patients may mistakenly think that human-made radiation is more dangerous than an equal amount of natural radiation. Most patients are unaware that most of their background radiation comes from natural radioactivity in their own body. Radiologists and radiographers should explain to them that we are all radioactive. A typical adult has over 9 kBq of natural radioactivity (i.e. 9 000 radioactive disintegrations in our body each second - over a half million per minute). The resulting radiation strikes billions of our cells each day. In a year, essentially all of the trillions of cells in our body have been hit by background radiation. The idea that radiation to one cell can initiate cancer is illogical - it assumes that the body has no defense or repair mechanisms. The body has several defense mechanisms to protect itself from doses up to about 200 mGy.[4]

Most patients never see the radiologist. Questions about radiation are often asked of the radiographer. Radiographers are generally not prepared to answer a patient's question about radiation dose. However, if tables of effective dose and BERT are available at each x-ray unit, any radiographer can answer the patient's question about radiation dose. (See Table I.) If the patient desires further information the radiographer should recommend a basic book, such as 'Understanding Radiation'. [7]

4. The extent of the usage of BERT concept

The BERT concept is used widely in many countries, including Australia, Ireland, U.K. and some parts in the U.S.A., to explain and educate doctors, medical students, radiology trainees, residents, radiographers, nurses, and technologists, about radiation doses received by patients. This concept has also been published in several publications. For example, the Royal College of Radiologists (RCR) in the U.K. has published a guidelines booklet ' Making the Best Use of a Department of Clinical Radiology – Guidelines for Doctors' [5] in which the BERT concept is used to rank radiographic examinations in order of dose level. Similar information was presented in an Australian radiology textbook 'Applied Imaging Technology' [8] and 'Guidelines for Clinical Practice in Radiology' published by the Malaysian Radiological Society [9]. A table listing typical effective doses along with the BERT values is presented in the home page of the National Radiological Protection Board (NRPB) of the U.K. [6]

Recently we carried out an online survey via the largest medical physics list (medphys@lists.wayne.edu) and received many positive responses. Here are some excerpts of comments and feedback:

- "It empowers patients to make more informed decisions about risk."
- "I think the BERT is a great idea and the relation to natural background is the best thing about it; my guess is most radiation safety people use this approach, but not the specific unit."
- "I do not use it specifically but nearly always explain the dose from any procedure which a patient may receive in terms of a comparison with the ever present background radiation."
- "I've used it when explaining exposure to the families of permanent prostate implant patients. None have ever found it insulting or patronizing, and most are relieved to finally have something familiar to which they can equate their radiation exposure."
- "I have found it to be very useful and very well received and understood. Occupational and non-occupational workers seem to understand very clearly the concept of BERT. I think relating radiation exposure received to background is very wise. Haven't many of us been doing that very thing in an informal way for some time?"

Table I. Typical effective doses and equivalent periods of natural background radiation [5,6]

X-ray examinations	Typical effective dose (mSv)	BERT (Background Equivalent Radiation Time)[1]
Limbs and joints (except hip)	<0.01	<1.5 days
Teeth (single bitewing)	<0.01	<1.5 days
(panoramic)	0.01	1.5 days
Chest (single PA film)	0.02	3 days
Skull	0.07	11 days
Cervical spine (neck)	0.08	2 weeks
Hip	0.3	7 weeks
Thoracic spine	0.7	4 months
Pelvis	0.7	4 months
Abdomen	0.7	4 months
Lumbar spine	1.3	7 months
Barium swallow	1.5	8 months
IVU (kidneys and bladder)	2.5	14 months
Barium meal	3	16 months
Barium follow	3	16 months
Barium enema	7	3.2 years
CT head	2	1 year
CT chest	8	3.6 years
CT abdomen/pelvis	10	4.5 years

[1]Natural background radiation based on UK average = 2.2 mSv per year.

4. Summary and recommendations

Radiation phobia can be greatly reduced by explaining the diagnostic radiation dose to the patient using the BERT concept. Medical physicists have a responsibility to educate radiologists and radiographers how to use the BERT concept and to provide them with tables of BERT values for each clinical x-ray unit. Radiologists and radiographers have a responsibility to educate patients and others who ask them about radiation.. The BERT concept is understandable, it does not suggest any risk and it educates the patient about background radiation. BERT is not a radiation quantity. It is a method of explaining radiation to the public. The word BERT is never used in the explanation.

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FORM B
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OCCUPATIONAL DOSE OF RADIATION WORKERS IN SERPONG RESEARCH CENTER FROM 1994 TO 1999

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Abstract :

Radiation workers in Serpong Research Center has been monitored by external and internal radiation monitoring program. The external radiation is monitored using thermoluminescence dosemeter (TLD), while internal radiation monitoring is carried out using Whole Body Counter (WBC) and urine analysis. The results of monitoring during 1994 to 1999 indicated that most of the radiation workers received doses far bellow the permitted dose, i.e. 95 % of workers received external dose in the range of 0 – 4 mSv and 98 % of radiation workers who has internal radiation monitoring, received internal dose in the range of 0 - 4 mSv.

1. Introduction

Research center in Serpong is one of research center for nuclear energy that belongs to National Nuclear Energy Agency (BATAN). There are some nuclear facilities in this area such as nuclear fuel element fabrication, 30 MW multi purpose reactor (MPR-30), radioisotope production center and radioactive waste management center. Radiation workers involved in those activities are about 650 workers besides non-radiation workers. Those radiation workers, depend on the type and job activities, might get exposed by external and/or internal radiation.

To protect and prevent the radiation workers from any radiation effects or diseases, the company has made a radiation protection program which include the monitoring of radiation dose received by the workers. This program has been carried out since 1987, or since the research center being operated, by the Environmental and Radiation Safety Division of Radioactive Waste Management Center. But this division only responsible in monitoring process while the interpretation of monitoring results and decision of further investigation or action are the responsibilities of each facility i.e. the radiation safety division of the facility. The decision of workers who should be monitored and the procedures of monitoring, was taken with consideration of recommendations of National Nuclear Energy Agency (BATAN), the International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) or other international radiation protection organizations [1,2].

This paper will present the results of the personal radiation dose monitoring during the last 5 (five) years (1994 - 1999) including the action that was taken if the radiation workers receive, or tend to receive, doses exceeding the dose level e.q. 60 % of dose limit. Results and discussion here are based on the recommendations of ICRP No. 26 (1982), because up till now Indonesia or BATAN, has not implemented the recommendations from ICRP No. 60 yet. Nuclear facilities in Indonesia were designed, constructed and operated based on the former recommendations. The new recommendations and other safety standard released by IAEA or ICRP are still being studied and learned continuously by the competent authorities, which are BAPETEN and BATAN, to be implemented and applied in Indonesia.

2. Methodology

Personal radiation dose monitoring is divided into two methods, which are external radiation monitoring and internal radiation monitoring.

External radiation monitoring is carried out using thermoluminescense dosemeter (TLD) in a card shape of BG-71 and BGN-7767 type. These TLDs could detect β, γ, x-ray and neutron radiation in the dose range of 10 μSv 10 1 Sv [3]. Every worker who works with or in radiation area

, must wear this TLD and everyone was given 2 TLDs with 3 months period of wearing for each TLD. TLDs are read using a semiautomatic TLD reader of 6600 model from Harshaw. This equipment is completed with a software for analysing the dose, which is called the Radiation Evaluation and Management System (REMS). Calibration of TLD reader is carried out once a year using ^{60}Co and ^{137}Cs standard sources. The results of TLD evaluation are reported as dose, which are skin dose (H_S) and whole body or deep dose (H_D).

Internal radiation dose monitoring is carried out using in-vivo or direct method and in-vitro or indirect method, but these internal monitoring only required for radiation workers who works in Working Condition A [2] defined as being where annual dose (external + internal dose) might exceed 0.3 of dose limit. Direct method is a method to monitor and detects the X and γ rays emitted by the inhaled, ingested or injected radionuclides in the body, using Whole Body Counter (WBC) ACCUSCAN-II from Cannberra USA. The counting are performed in a shielded room to reduce the background radiation which could influence the counting results. The whole body counter we used is a vertical scanning type and equipped with a high purity germanium detector (HpGe) that can detect energy in the range of 50 keV to 10 MeV [4]. Software for operating the counter and analysing the quality and quantity of contaminants detected is called the ABACOS-PC. Calibration of this counter is carried out once a year using mixed gamma standard source and RMC-II phantom.

Indirect method is analysis of excreta, i.e urine analysis, to detect the contamination of radionuclide in radiation worker's body. The analysis are using some radiochemical analysis procedures which refer to the standard procedure. The counter which are used to count the urine samples are γ-Spectrometer and Low background α/β Counter. These counters are also calibrated every year using standard sources of ^{152}Eu and ^{90}Sr. Internal radiation dose monitoring with this indirect method is carried out periodically with a frequency of 3 or 6 months depend on the radionuclides involved in the facility's activities.

The results of both direct and indirect methods are reported as Committed Dose Equivalent (CDE) and Committed Effective Dose Equivalent (CEDE), and also intake or uptake of radionuclides if necessary. The estimation and calculation of intake and doses are based on metabolic model of radionuclides in human body. The metabolic data of these radiouclides, such as distibution, retention and excretion function, inhalation class and dosimetric data of radionuclides are referred to the ICRP Publication and its supplements i.e ICRP No. 10, 30 and 54 [5, 6, 7]. Software for calculating the intake and dose have also been made to make the work of evaluation easier, and it is called the Personal Radiation Dose Information System written in Borland Delphi 3 language.

3. Results and Discussion

During these last 5 years (1994 -1999), the radiation workers who has been monitored with external radiation monitoring and internal radiation monitoring, in average, are 650 workers/ year and 250 workers/year respectively.

The results of external radiation monitoring indicated that the minimum dose received by the workers were 0.07 mSv for H_S and 0.05 mSv for H_D, whereas the maximum dose received were 78.82 mSv for H_S and 65.54 mSv for H_D...

For internal radiation monitoring, the results indicated that the minimum dose received were 1.70 mSv for CEDE and 0.04 mSv for CDE, whereas the maximum dose received were 19.16 mSv for CEDE and 4.33 mSv for CDE. The distribution of dose received by radiation workers in 1994 to 1999 are shown in Fig. 1 for external dose and Fig. 2 for internal dose.

These results, generally indicated that the dose received by radiation workers are low compared to the dose limit for radiation workers of 50 mSv for H_D and CDE or 500 mSv for H_S and CEDE. From Fig.1 we could see that approximately 95 % of workers received H_S and H_D (external dose) in the range of 0 to 4 mSv and the rest were distributed in the range of 4.1 mSv to 66 mSv. Fig.2 give an information that about 98 % of monitored radiation workers received internal dose

CEDE and CDE, in the range of 0 - 4 mSv, and the rest were distributed in the dose range of 4.1 mSv to 28 mSv.

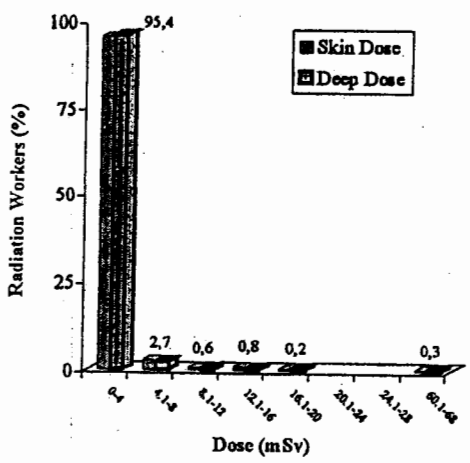

Fig.1. Distribution of External Radiation Dose from 1994 - 1999

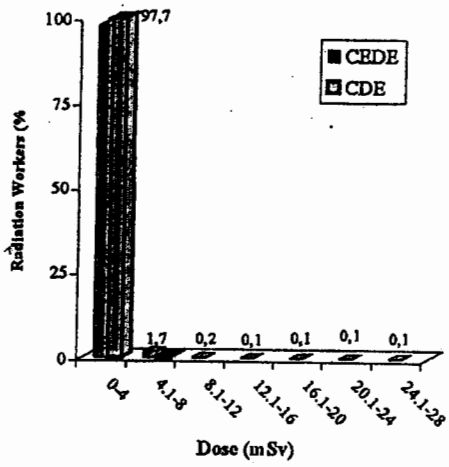

Fig.2. Distribution of Internal Radiation Dose from 1994 - 1999

The high dose receiving during these 5 years were only 4 cases, which was happen in 1997/1998 with the maximum external dose (H_D) of 65.54 mSv. Those who received the high dose the high dose were they who work at the radioisotope production, multipurpose reactor and some of radiography operator. Action and investigation has been taken over these cases, and the radiation workers who involved in the high doses have been medically check-up. The medical check-up consists of blood and physical check and was carried out by the medical doctors. The results of medical check-up indicated no abnormalities, neither in the blood components nor in the physical body. Nevertheless, the involved radiation workers always monitored by doctors and they were also assigned to the non-radiation area for at least 1 (one) year as recommended by the Nuclear Energy Control Board (BAPETEN). Further investigation of the case found that the high dose was probably caused by an accidentally exposure that was received by the TLD which was stored not in a proper place. For these reasons, the involved radiation workers has been given a warning and the procedures and manual of dosemeter application has been revised.

For internal radiation monitoring there were no significant results during these last five years. Even there were some radionuclides detected in the radiation worker's body, but the maximum dose received was only 4.33 mSv (CDE) whereas the dose limit is 50 mSv. The radionuclides detected in the body were mostly caused by fission products such as ^{131}I, ^{95}Zr, ^{95}Nb or ^{192}Ir and was detected in the body of radioisotope production's workers. The facility of radioisotope production produces some radioisotopes that are used for nuclear medicine. Although the radionuclides detected in the body were far below the limit, the radiation workers are always reminded to protect themselves from contamination by wearing protection devices, such as gloves, respirators, shoe covers, protective clothing, etc. The condition of working area also have an important role in internal radiation contamination, that is why monitoring of working area are should also be performed continously.

A reference [8] gave an information that population of 10^6 persons who received dose of 1 mSv per person or a total collective dose of 1000 ManSv, could give a probability for fatal cancer of 13 cases. Based on that reference and the results of radiation dose monitoring in Serpong Research Center with 650 workers and average dose received of 1.09 mSv or collective dose of 0.709 mSv (the four high doses excluded), the probality of fatal cancer for that population is 5.65 x

10^{-12}. This means that the probability of the arising of fatal cancer in the radiation workers of Serpong Research Center due to the radiation dose received in the period of 1994 to 1999 is very small.

As mentioned before in the introduction, the results here are compared to the recommendations of ICRP No.26 which use dose limit of 50 mSv for radiation workers. But when we refer to the new recommendations ICRP No. 60 which apply dose limit of 20 mSv, much of the doses received by workers in these five years period will probably be over the dose limit. Up till now Indonesia has not implemented the new recommendations yet, because implementation of new recommendations will affect many aspects such as design and constructions of the facility's building, process and operations of the facilities and also the safety program. To make changes of those are not easy and need a lot of study and cost. These days, the study of new recommendations are still in progress. BAPETEN, as the competent authority in nuclear energy control in Indonesia, will soon released the regulations in implementation and applications of ICRP No. 60 recommendations.

4. Conclusion

The occupational dose received by radiation workers in Serpong Research Center are mostly far below the permitted dose or dose limit. The health and safety of the workers are also in good condition because up till now there are no evidence of any diseases or abnormalities found in the workers that caused by the occupational dose. Nevertheless, efforts to develop the radiation monitoring program is always been done, such as increasing the coordination with the radiation safety division of each facility, the management of monitoring and also increasing the capabilities of the human resources in radiation protection. Besides that, new recommendations are also learned and studied to see the probability of application in our nuclear facilities and to learn the changes that must be done in radiation protection program.

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RADIATION DOSES TO PATIENTS IN DIAGNOSTIC RADIOLOGY IN ROMANIA; COMPARISON WITH GUIDANCE LEVELS AND POSSIBILITIES OF REDUCTION

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Abstract

During 1990-2000 the Institute of Public Health-Bucharest participated to two research programmes, co-ordinated by International Atomic Energy Agency, in co-operation with European Commission. Patient dose measurements were performed in 10 X-ray units from 5 big hospitals from Romania, for the main X-ray diagnostic procedures using thermoluminescent dosemeters (TLDs). The obtained values were compared with the internationally recommended guidance levels. The highest ratio patient surface entrance dose/ guidance level was determined for chest radiography due to the routine practice of using low "kV" technique.

A special attention was given also to conventional fluoroscopy (direct viewing), still in use in about 20% of the total X-ray examinations in Romania.

1. Introduction

According to the definition, in X-ray diagnostic radiology, a Guidance Level (GL) is a dose level set for standard procedures and for groups of standard-sized patients or a standard phantom:

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

Consistent guidance levels are given by International Atomic Energy Agency in Basic Safety Standards from 1996 [1] and by European Commission in its guidances from 1996 and 1999 [2,3].

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

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

Since the beginnings of 1990, the Institute of Public Health-Bucharest participated to the co-ordinated research programmes (CRPs) on "Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction" [4] and on "Technologies for Dose Reduction in Diagnostic Radiology for Eastern European Countries", initiated by the International Atomic Energy Agency, in co-operation with European Commission.

2. Method

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

The entrance surface dose on patient in medical radiography was directly measured by means of TL dosemeters, after an intercalibration of all participating laboratories to the CRP. A set of dosemeters from each participant was exposed in the same laboratory to different beams (25, 60, 80 and 120 kV and ^{137}Cs) and to different doses (0, 1, 5 and 50 mGy).

The dose-area product and dose rate in fluoroscopy were determined using appropriate calibrated ion chambers type PTW-Freiburg.

When performing measurements on the patient, several relevant data were collected: equipment generator and X-ray tubes imaging system and processing, patient data and technical factors (settings, distances, exposure time) for each examinations.

After a comparison with guidance levels, an analysis of the results was performed, in order to identify the causes which contribute most to the dose and, if appropriate, dose reduction methods were applied, keeping the image quality [3].

3. Results

In Table 1 are presented the measured entrance doses to patient for the main radiographic examinations and projections. The mean value ranged from 45.3 mGy for thoracic spine (LAT) to 1.1 mGy for chest (PA). The ratio between the measured (mean) dose and guidance level [1] varies from 1.0 for cholecystography (AP) to max. 2.8 for chest (PA).

Table 1 – Patient doses (adults) for diagnostic radiography

Type of examination and projection		Measured entrance dose (mGy)		Guidance Level	Ratio (M/G)
		Range	Mean value		
SKULL	AP	4.7 – 19.0	9.1	5	1.8
	LAT	4.4 – 14.5	6.9	3	2.3
CHEST	PA	0.5 – 1.5	1.1	0.4	2.8
	LAT	1.0 – 3.1	1.8	1.5	1.2
THORACIC SPINE	AP	6.5 – 20.6	12.0	7	1.7
	LAT	19.2 – 55.0	35.6	20	1.8
LUMBAR SPINE	AP	7.4 – 25.8	16.8	10	1.7
	LAT	26.0 – 72.8	45.3	30	1.5
ABDOMEN	AP	10.7 – 21.3	14.2	10	1.4
PELVIS	AP	9.6 – 24.4	16.6	10	1.7
CHOLECYSTOGRAPHY	AP	7.8 – 15.8	10.1	10	1.0

The calculated effective doses are given in Table 2.

Table 2 – Effective dose per radiographic procedure

Procedure	Effective dose per radiographic procedure (mSv)
SKULL	0.17 (± 0.09)
CHEST	0.25 (± 0.11)
THORACIC SPINE	2.00 (± 1.20)

LUMBAR SPINE	**2.93 (± 1.40)**
ABDOMEN	**1.90 (± 1.10)**
PELVIS	**2.60 (±1.30)**
CHOLECYSTOGRAPHY	**1.60 (± 0.90)**

In Table 3 are shown the dose-area product values obtained for fluoroscopic procedures (the barium examinations include also the radiographic images) and the calculated effective doses.

Table 3 – Patient doses in fluoroscopic procedures

Procedure	Dose – Area Product (Gy . cm^2)		Effective Dose (mSv)
	Range	Mean value	
Chest fluoroscopy	**4.3 – 10.7**	**7.5**	**0.95**
Barium meal	**11.0 – 30.0**	**20.5**	**4.10**
Barium enema	**18.5 – 45.7**	**32.1**	**9.10**

The Table 4 presents the range of measured entrance surface dose rates for conventional fluoroscopic installations (direct viewing) and the comparison with guidance value.

Table 4 – Entrance surface dose rates (mGy/ min)

Settings for chest fluoroscopy			Dose rate	
kV range	mA range	total filtration mm Al	Measured	Guidance
70 - 85	**2.5 – 3.0**	**2.5**	**22 – 49.5**	**25**

4. Dose reduction

For the very frequent chest radiography, the analysis of physical parameters used (Table 5) shown that a low "kV" technique is generally preferred, explained by the care to protect X-ray tube.

Table 5 – Physical parameters used and comparison with recommended values for chest radiography

Parameter	Used	Guidance
FFD (cm)	**160 (150-170)**	**180 (140-200)**
kV	**75 (70-80)**	**125**
Speed of film/ screen combination	**200**	**400**

By increasing of kV and reduction of both mA.s and field size a dose reduction up to 30 % was obtained, keeping the quality of image.

An increase of screen-film sensitivity determined a dose reduction up to 40 %.

Important possibilities for dose reduction are available in fluoroscopy. In Romania 20 % of the total X-ray examinations are fluoroscopies and 80 % of fluoroscopies are for chest, most of them still using conventional (direct viewing) fluoroscopy. According to Art. 8 of Conncil Directive 97/ 43/ EURATOM of 30 June

1997 [5], such techniques are considered unjustified and should be prohibited in the future.

Important practical possibilities for dose reduction are available in fluoroscopy: use of as low mA and kV factors as possible, attention to a good collimation, short duration of investigation, dispense with antiscatter grids and others well known good practices.

5. Conclusions

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

As the guidance levels from basic safety standards are based on investigations in some developed countries, they are too restrictive for some other countries.

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

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ACCURATE ASSESSMENT OF THE DISTORTIONS PRODUCED BY THE TRANSIT DOSE IN HDR BRACHYTHERAPY.

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Abstract

Current polynomial methods used in the modelling of the dose distributions in HDR brachytherapy have been reformulated to improve accuracy. An example is provided to show the effects of the transit dose on the output. The transit dose, which is neglected by current computer software for calculating doses, can result in significant dosimetric errors. These additional unrecognised doses imply over-dosing and distortions in the dose distributions within the irradiated volume. Assessment of dose to critical and radiosensitive organs is therefore inaccurate. These could increase late tissue complications as predicted by the Linear Quadratic Model. Our model works very well for straight catheters and is highly recommended for the evaluation of the transit dose around such catheters.

ACCURATE ASSESSMENT OF THE DISTORTIONS PRODUCED BY THE TRANSIT DOSE IN HDR BRACHYTHERAPY.

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Abstract

Current polynomial methods used in the modelling of the dose distributions in HDR brachytherapy have been reformulated to improve accuracy. An example is provided to show the effects of the transit dose on the output. The transit dose, which is neglected by current computer software for calculating doses, can result in significant dosimetric errors. These additional unrecognised doses imply over-dosing and distortions in the dose distributions within the irradiated volume. Assessment of dose to critical and radiosensitive organs is therefore inaccurate. These could increase late tissue complications as predicted by the Linear Quadratic Model. Our model works very well for straight catheters and is highly recommended for the evaluation of the transit dose around such catheters.

1. Introduction

Every HDR application results in source dwell and transit doses. Dose calculation formalisms that incorporate the transit dose have been suggested for dose calculations in HDR brachytherapy by Houdek *et al* [1], Bastin *et al* [2] and later improved by Cho and Muller-Runkel [3]. Houdek's [1] report on the determination of the transit dose was an oversimplification as it assumed that none other than the inverse square law attenuation was involved. Bastin *et al* [2] made direct measurements with TLD chips as well as writing an algorithm to represent the transit dose distributions in HDR brachytherapy but observed a startling difference of *18.2 %* (on the average) between their measured values and their own algorithm. This is not surprising, as they assumed isotropic dose distributions, coupled with errors introduced by the finite sizes of the TLD chips. Cho and Muller-Runkel [3] incorporated anisotropy but assumed anisotropy does not depend on radial distance. This could lead to very serious errors as there is, on the average uncertainties of ± 10 %, from distances within a short range of *1 - 10 cm* from the centre of the source.

In this investigation, current recommended parameters [4,5,6,7] have been used. The anisotropy and the radial dose distribution functions have been hybridised and a model for the calculation of the transit doses, based on the hybridised function, is developed.

2. Method

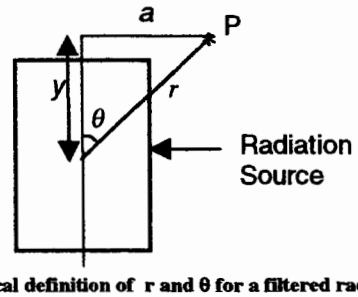

figure 1. The geometrical definition of r and θ for a filtered radiation source

The dose rate at a point P above is defined as follows [7,8,9].

$$\dot{D}(r,\theta) = S_k \Lambda_0 \frac{G(r,\theta)}{G(r_0,\theta_0)} F(r,\theta)\, g(r) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

From point – source approximation $G(r,\theta)=1/r^2$ [10] where $r^2 = y^2+a^2$. Now $G(r_0,\theta_0)$ and Λ_0 are

constants and the product $g(r)F(r,\theta)$ is a function of the linear displacement y as shown in fig. 1 and so

$$\frac{\Lambda_0 g(r)F(r,\theta)}{G(r_0,\theta_0)} = F(y)\ \{function\ \ of\ \ y\} \quad \therefore\ \ d[D(r,\theta)] = S_k \frac{F(y)}{y^2+a^2}dt.$$

Generally $G(r_0,\theta_0) = 1$. From the relationship between y and $F(y)$, we make use of a linear-linear polynomial expressed to the minimum possible degree to represent $F(y)$ hence $F(y) = A + By + Cy^2$ where A, B & C are constants. The source attains a finite velocity V when in motion, resulting in transit dose of magnitude $D(r,\theta)$ deposited at a point P and satisfies

$$V = \frac{dy}{dt} \therefore dt = \frac{dy}{V} \Rightarrow d[D(r,\theta)] = S_k \frac{F(y)}{y^2+a^2}\frac{dy}{V} \quad \ldots\ldots\ (2)$$

When the source moves from position y_1 to position y_2 with an average velocity V,

$$D(r,\theta) = \frac{S_k}{V}\int_{y_1}^{y_2}\frac{A+By+Cy^2}{y^2+a^2}dy = \frac{S_k}{V}\left[Cy + \frac{D}{a}\arctan\left(\frac{y}{a}\right) + \frac{B}{2}\ln(y^2+a^2)\right]_{y_1}^{y_2} \quad \ldots\ldots\ldots\ (3)$$

where $D = A - Ca^2$.

Assuming none other than the inverse square law attenuation,

$$D(r,\theta) = \frac{S_k\Lambda_0}{aV}\left[\arctan\left(\frac{y}{a}\right)\right]_{y_1}^{y_2} \quad \ldots\ldots\ (4)$$

When a = 0 eqn. (3) and eqn. (4) become

$$D(r,\theta) = \frac{S_k}{V}\left[\frac{-A}{y} + B\ln y + Cy\right]_{y_1}^{y_2} \quad \ldots\ldots\ldots\ (5)$$

and $D(r,\theta) = \frac{S_k\Lambda_0}{V}\left[\frac{-1}{y}\right]_{y_1}^{y_2}$ ..... (6) **respectively.**

2.1 Calculations and Results

Figure 2 below simulates a linear implant with (thirteen) 13-dwell positions and an inter-dwell spacing of *0.25 cm*. A,B,C & D are calculation points.

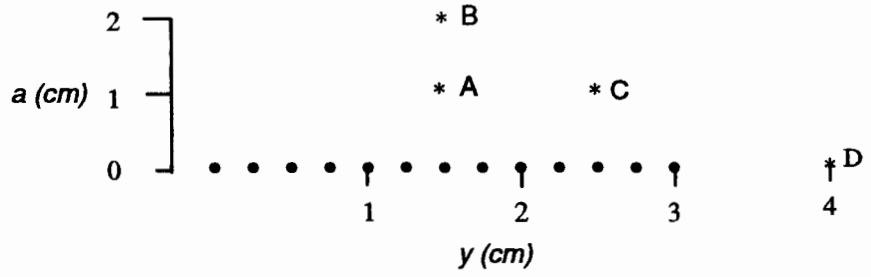

Figure 2. Illustration of example: •, dwell point; *, calculation point

The value of S_k is *11.3056 cGy cm² s⁻¹* [11] and Λ_0 = *1.111* [12] for a *370 GBq* ^{192}Ir source (Mallinckroft Medical B. V.). V was obtained from the table provided by Houdek *et al* [1]. The inter-dwell transit doses and the exit doses within the same region, D_T were calculated from eqns. (3) & (5). If the volume of tissue preceding the proximal dwell site is negligibly small, the entry and exit transit doses D_E (resulting from the travel between the HDR unit and the proximal dwell site) could be evaluated from eqns. (4) & (6). The total transit dose is hence $D_{ET} = D_E + D_T$. Anisotropy and radial dose profile data generated by Russell *et al* [12] has been used in our dose calculations. The Computer Programme MATTLAB was used to evaluate the constants A, B & C in the expression

$F(y) = A + By + Cy^2$ for $0 < \theta < \pi/2$ and $\pi/2 < \theta < \pi$ respectively, within the range $0 \leq y \leq 20$ *cm*. Within this range the data was split into two depending on the point at which we observed a discontinuity in the dependence of $F(y)$ on y. For the special angles $\theta = 0, \pi/2$ & π the desired accuracy was achieved by using one single equation to parametrize $F(y)$.

TABLE I: Calculated transit doses D_T, D_E & D_{ET} at selected points:

	A	B	C	D
$D_T(cGy)$	1.918	0.630	1.616	0.489
$D_E(cGy)$	0.291	0.228	0.186	0.121
$D_{ET}(cGy)$	2.209	0.858	1.802	0.610

3. Discussion and Conclusion

The best results, for example those compatible with the objectives of HDR conformal brachytherapy are obtained by using small inter-dwell distances, that in turn permit fine variation of dwell times. Transit doses are however higher for such distances as the speeds are relatively low. To reduce the risk of late tissue complications, an increased fractionation schedule is applied in HDR relative to LDR brachytherapy. Since source movement is inherent during each HDR treatment cycle, the total transit dose is linearly increased with the number of fractions. Higher transit doses are therefore experienced in order to achieve the best results in HDR brachytherapy. The transit dose is directly proportional to the source strength and smaller catheter diameters will also increase the transit surface doses to proximal tissues. All together, the transit dose has no definite relationship with the static dose but varies widely among patients and different treatment schedules. This leads to over-dosing and more seriously, a distortion of the dose distributions within the irradiated volume.

Consider for example the case of "base of tongue" cancer being treated with interstitial brachytherapy. A common fractionation schedule is to give *3 Gy / fraction / twice / day*. If *3 Gy* is given at a distance of *1 cm* from a straight catheter we observed that the transit dose contributed, on the average up to *0.7 %* of the total dose. For three of such catheters parallel to each other separated by *1.0 cm* the total transit dose at the prescription point "A" (with respect to the central catheter) works out to be *5.3 cGy*. Extending this to two of such planes parallel to each other such that one is exactly above the other and separated by just *0.5 cm*, the transit dose is seen to contribute up to *3.4 %* of the total dose at point "A". So, as the complexity of the implant increases the contribution by the transit dose becomes more significant and can go above *10 %*, in addition to the distortions that may result. From the magnitude of the contributions by the transit dose only, we may be operating outside acceptable limits if the transit dose is neglected and this will go a long way to affect the outcome of treatment.

Our model reproduced the data used [12] within an accuracy of *0.05 %*, which is a marked improvement over the work done by earlier investigators [1,2,3]. On the whole, the physical sizes and shapes of patients as well as heterogeneity effects have not been taken into account. The calculations were based on data from an infinite homogenous phantom [12]. We have started some work on applicators of complex geometry, using Monte Carlo Simulations. Heterogeneity effects from tissues, internal shields and air will be addressed. Scatter integration algorithms will also be written to correct for finite patient sizes and shapes.

Brachytherapy using high dose rate afterloading is increasingly used worldwide for treating interstitial, intracavitary, intraluminal and percutaneous malignancies, owing to its inherent advantages over standard LDR brachytherapy. Current computer software for calculating doses in HDR brachytherapy neglects the transit dose. The contribution of the transit dose to the total dose is however very significant in some cases, especially if we aim at true conformal therapy, in line with the principles of HDR brachytherapy. A failure to account for the transit dose therefore means unreliable output in

dosimetry. We strongly advocate for the transit dose to be incorporated into all high dose rate treatment planning systems. This will ensure accuracy in prescription and the assessment of potential risks to patients. Our model works very well for straight catheters and we recommend this very highly for the calculation of doses around such catheters. Apart from the example discussed, our model would be equally useful when the transit path preceding the proximal dwell site goes through an appreciable thickness of tissue e.g. in the case of endobronchial brachytherapy. With further development, the methods of calculation could be simplified, whilst not compromising accuracy.

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A CASE REPORT; THE FIRST AND SUCCESSFUL CASE OF INTRALUMINAL RADIATION THERAPY TO A CARCINOMA OESOPHAGUS PATIENT IN MYANMAR BY LOCALLY AVAILABLE APPLICATOR

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Abstract:

In Myanmar, the inoperable carcinoma oesophagus cases are treated with external radiation therapy alone. The aim is just palliative. Survival and symptom free survival are not good. In January 2000, our institute received Caesium sources of same external length with different activity from International Atomic Energy Agency. The first case of inoperable carcinoma of oesophagus was treated with external and intraluminal radiation therapy. Instead of standard applicator for intraluminal therapy, the applicator was designed to fit for the sources with locally available plastic tube and 14-gauged Ryle's gastric suction tube. First the patient was treated with 200 cGy per fraction for 3800 cGy within 26 days and followed by 1275 cGy 1 cm from axis of intraluminal sources within 8.5 hours. The intraluminal plastic tube (equivalent of 22-gauged of Ryle's tube) that can be easily assemble with 14-gauged Ryle's tube containing Caesium sources. This plastic tube was instead through the mouth by thoracic surgeon when the patient was under general anaesthesia. 14-gauged Ryle's tube was first loaded with dummy sources and inserted through the plastic tube. The simulation films were done to confirm that the dummy sources were in the planned places. After simulation, the Caesium sources loaded 14-gauged Ryle's tube was inserted into the target places until it was confirmed by 3 X-rays films (our facility could not use fluoroscopy). The longitudinal 5 different Caesium sources were used and the dose distribution was done by RadPlan computer system (designed by India). Therapy was successful and the patient was free of dysphagia during surviving. The reasons to present this case are 1) the quality of life is improved by increasing in dysphagia free survival, 2) the reduction of treatment time (from 10 days to 2 days) and duration of hospital stay, and the advantage of cost and effectiveness, and 3) the reduction of radiation exposure to the patient and medical personals.

Introduction:

Patients with oesophagus carcinoma may be surgically unresectable because of extent of tumour locally or metastases distally. These patients require relief from dysphagia and pain. Numerous modalities are available for palliation of symptoms of oesophageal obstruction, including external-been irradiation, Intraluminal brachytherapy intubation through the tumour with various prostheses, placement of stents, laser opening of the

occluded oesophagus, and simple dilation. The application of a given method of palliation depends to a great extent on the patient's physical condition and the expertise of the thoracic surgeon and radiation oncologist.

Patients with symptomatic oesophageal carcinoma not amenable to surgical resection and previously treated with external beam irradiation may be candidates for intraluminal brachytherapy. In this procedure, a radioactive head is placed through a catheter prepositoned through the area to be irradiated. This radioactive source passes through the area in a given amount of time to provide a finite of penetration of the radiation rarely exceeds 2 to 3 cm. [1, 2] There are several intraluminal brachytherapy treatments and good results to advanced carcinoma of oesophagus. For examples, Sur and colleagues treated 9 patients with advanced squamous cell carcinoma of the middle third of the oesophagus with intraluminal brachytherapy. Even without previous external beam irradiation, intraluminal brachytherapy may be effective.[3] Fleischman and colleagues showed that 9 of 10 patients with advanced oesophageal cancer treated with intraluminal brachytherapy achieved palliation equivalent to that of external beam irradiation. Most patients had already experienced failures of other palliative modalities.[4] Holting and colleagues successfully used laser and intraluminal brachytherapy in 16 of 45 patients (previously treated with laser) to prolong palliation.[5]

On the other hand, most of the developing countries have no remote after loading systems and special applicators for intraluminal brachytherapy. In Myanmar, Yangon General Hospital (YGH) had fixed caesium sources for gynaecological applicators so the inoperable oesophageal cancer patients were treated with only external radiation. Recently, YGH has already received Amershan type gynaecological applicators and unfixed, rearrangable, same external length caesium sources with different activities (same external length 20 mm but different activities 21, 25, 37.5, and 41 mCi) by kind provision of the International atomic energy agency (IAEA) in January, 2000. We present a method, which can be performed in the radiotherapy centre with a teletherapy machine and Amershan gynaecological brachytherapy sources.

Case description:

The first case of inoperable oesophageal cancer patient was treated with external radiation therapy and intraluminal brachytherapy by our team. The patient was treated with 200 cGy per day, five days a week for total 3800 cGy followed by intraluminal brachytherapy for 1275 cGy at 1 cm from central axis, after two weeks interval from external radiation. First external radiation therapy was reported according to ICRU-50; report and brachytherapy method was described separately.[6]

Case report (ICRU-50):

CLINICAL SITUATION;

69 years old male, Buddhist monk, presented with progress dysphagia for 2 months. Endoscopy revealed tumour in the oesophagus at 35 cm from the incisor tooth. Biopsy concluded as invasive, well-differentiated squamous cell carcinoma G2. Barium study showed the tumour length more than 8-cm. No CT scan or MR examination was done. T3 Nx Mx disease, clinical stage II to III.

AIM OFTHERAPY; Patient is inoperable. Palliation radiotherapy for the purpose of relieving dysphagia is planned.

GTV; Primary tumour + subclinical extensions [C15.4-5]

CTV; CTV I: GTV + possible mediastinal lymphnodes [C77.1A-B]

PTV; CTV I + 2-cm margin is added to allow for respiratory movements and variation in beam set up.

ORAGANS AT RISK; A: Spinal cord [C72.0B].
B: Both lungs [C34.9-1,2]
C: Heart [C38.0]

PRESCRIBED DOSES; PTV I: 38 Gy in 19 fractions over 4 weeks.

ACCEPED DOSES TO ORGANS AT RISK; A: Less than 35 Gy in 10 fractions. B: As low as possible. C: 30 Gy in at most 30 cm^3.

TENTATIVE TECHNIQUE; AP-PA beams.

PATIENT POSITIONIOING AND IMMOBILIZATION; Supine with head on standard headrest and arms by side. No special patient fixation.

SECTION FOR DOSE PLANNING; The centre of the GTV.

DOSE CALCULATION; Central beam isodose data without inhomogenecity correction. Manual calculation.

TECHNIQUE;60CO. Two opposed equally weighted beams with direction 0 and 180 degree , respectively. SSD technique. Field width 8-cm (both). Field length 15-cm (both). No blocks and wedges.

CONTROL MEASURES; Barium swallow simulator films. No treatment verification films.

DOSE SPECIFICATION FOR REPORTING; 1. ICRU. Reference Point = midway between beams entrances, in the centre of the PTV (100%). 2. Maximum and minimum dose the PTV according to the calculation (167.5% and 100%). 3. Hot Spot (outside the PTV) = 167.5%.

Intraluminal brachytherapy:

Two weeks interval after external radiation, intraluminal brachytherapy was done. Barium swallow film rechecks revealed tumour shrinkage. We decided the planning target volume in the oesophagus 27- to 37-cm from the incisor tooth, with 1-cm depth. The patient was first introduced a plastic tube (22-gauged Ryle's tube size, 120-cm length, both ends open) through mouth to the stomach. The insertion was done by the thoracic surgeon under general anaesthesia in the operation theatre. When the patient recurred from general anaesthesia, the dummy loaded 14-gagued Ryle's tube was inserted into the plastic tube to the target position by guidance of the simulation films (our fluoroscopy potion of simulator was not functioning at that time) in the simulation room. The optimal simulation film was used for isodose calculation by using RADPLAN computer system. The sources were arranged as 21, 25, 37.5, 25, and 25 mCi longitudinally (21 is mouth end and 25 is stomach end) in the another14-gagued Ryle's tube. By computer calculation, the dose was decided 1275 cGy at 1-cm from axis and the total exposure time is 8.5 hours. The loaded 14-gagued Ryle's tube was

inserted in the simulator room and simulator films were done to get the sources in positions. When the loaded 14-gagued Ryle's tube was in the satisfactory position, patient was placed in

the special room during therapy and the attendance and nursing staffs monitored the patient from the radiation safe area. During therapy, patient was in parental feeding. Every step needs technical skill, good monitoring and nursing care, optimal radiation safety and spirit of teamwork. The operation was successful and the patient was well after operation and can swallow usual food after three days.

Conclusion:

Most of the oesophagus cancer cases are first detected at an incurable stage so palliation is the aim of therapy.[7,8] Intraluminal brachytherapy is the promising method in radiation therapy for palliation to advanced carcinoma oesophagus. This method can be performed in the limited resources centres where there are only teletherapy machine and Amershan gynaecology brachytherapy sources available, and can improve the patient's quality of life by reducing the radiation dose to the unnecessary normal tissues. The reasons to present this case are 1) the quality of life is improved by increasing in dysphagia free survival, 2) the reduction of treatment time (from 10 days to 2 days) and duration of hospital stay, and the advantage of cost and effectiveness, and 3) the reduction of radiation exposure to the patient and medical personals.

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Neutron dose to patients treated with high-energy medical accelerators

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Abstract

The neutron dose equivalent received by patients treated with high energy x-ray beams was measured in this research. A total of 13 different medical accelerators were evaluated in terms of the neutron dose equivalent in the patient plane and at the beam center. The neutron dose equivalent at the beam center was found to ranged from 0.02 to 9.4 mSv per Sv of x-ray dose and values from 0.029 to 2.58 mSv per Sv of x-ray were measured in the patient plane. It was concluded that the neutron levels meet the International Electrotechnical Commission standard for the patient plane. It was also concluded that when intensity modulated radiation treatment is conducted the neutron dose equivalent received by the patient will increase by a factor of 2 to 10.

1. Introduction

Medical accelerators are used routinely to produce high energy x-ray and electron beams for use in the treatment of cancer patients. The radiation beams generated by medical accelerators operated above 8 MeV are contaminated with neutrons as a result of photon reaction with the materials used to fabricate the accelerator structure. The dose equivalent produced by photoneutrons is of importance in assessing the risk to the patient due to stray radiation. In this work the dose equivalent in the patient plane and at the beam center was measured for a number of modern medical accelerators.

2. Materials and methods

Table I list the various accelerators investigated, the beam megavoltage as given by the American Association of Physicist Task Group-21 Protocol [1] and the stated energy indicated by the manufacturer.
Moderated activation detectors were used to determine the neutrons in the main beam and at points outside the x-ray beams. A 15.2 cm diameter paraffin moderator equipped with an indium foil at it's center was used to measure the fast neutron fluence at the beam center per unit dose of x-rays. at the isocenter. This dosimeter was utilized due to the relatively small size, which allowed it to be placed within a 20 x 20 cm^2 x-ray beam. The detector also has the desirable feature of having a small sensitivity to photons. The activity of the indium foil after an irradiation has been shown to be directly proportional

to the neutron fluence per unit dose of x-ray[2]. Since the detector has a flat energy response in the fast neutron energy region the energy spectrum of the neutrons does not have to be accurately known to determine the fast neutron fluence[2]. The moderator was encased in a cadmium thermal neutron shield to eliminate any response produced by thermal neutrons. The measurements were made at the center of beams of cross sectional area of 20 x 20 cm^2 at 1 m from the target. A ^{252}Cf neutron source was used to calibrate the moderated activation system. Factors[3] to account for neutrons produced in the cadmium thermal neutron shield by photons were applied to the measurements. The foil count rate was evaluated by use of a gas-flow proportional counter. Corrections of the count rate were made for lack of saturation and decay before and during counting. The neutron fluence established by use of the paraffin sphere was converted to neutron dose equivalent based on information given in NCRP Report No. 79[4].

TABLE I. Accelerators investigated, accelerator parameters, and the fast neutron equivalent per unit dose of x-rays at the beam center .

Accelerator	Stated energy (MeV)	TG-21 Megavoltage	Neutron dose equivalent per unit dose of x-ray at the isocenter (mSv/Gy x-ray)
1. Siemens KD	20	17.0	4.2
2. Siemens Primus	18	15.3	3.1
3. Siemens MD	15	13.2	1.4
4. Phillips SL25	25	22.0	8.0
5. Phillips SL20	20	17.0	2.3
6. GE Saturne 43	25	18.5	8.5
7. GE Saturne 43	18	14.0	5.1
8. GE Saturne 41	15	12.5	1.7
9. GE Saturne 41	12	11.2	0.8
10. Varian 2300	20	18.5	9.4
11. Varian 2300	18	17.5	8.3
12. Varian 2300	15	13.1	4.0
13. Varian Clinac 18	10	9.2	0.02

The neutron dose equivalent outside the beam was determined by use of a 25.4 cm diameter Bonner sphere with an indium foil placed at the center of the sphere. The Bonner sphere was used for these measurements because the neutron energy spectrum was not known for points outside of the beam and the response of 25.4 cm sphere is proportional to the neutron dose equivalent independent of the energy of the neutron field. A second reason the Bonner sphere dosimeter was chosen for measurements in the patient plane was that detailed knowledge of the accelerator head shielding was not required to establish the neutron dose equivalent. On the other hand, if the paraffin moderator had been used for the determination of the dose equivalent the thickness and type of materials in the accelerator head would have been required. The Bonner sphere system was calibrated with the same neutron source used to calibrate the paraffin sphere.

Neutron measurements were made in the patient plane, which is defined as the area formed by a one meter radius circle located one meter from the x-ray target at a right angle to the central axis of the beam. The sphere was positioned at 30 and 100 cm from the central axis of the x-ray beam in order to determine the dose equivalent received by the patient. The collimator of the accelerator was closed to the minimum size when measurements were made in the patient plane in order to maximum neutron production. The location of the points of measurement in the patient plane are indicated by G(toward the gantry), -G(away from the gantry, and left(Lf) and right(Rt) as viewed from the foot of the treatment table looking toward the gantry.

Table II. Neutron dose equivalent(mSv) in the patient plane per unit dose(Gy) of x-ray at the isocenter.

Distance from beam center	30 cm				100 cm			
Accelerator Number	-G	G	Lf	Rt	-G	G	Lf	Rt
1	1.40	1.40	1.60	1.40	1.00	1.10	1.20	1.00
2	0.49	0.47	0.50	0.45	0.45	0.44	0.49	0.44
3	0.31	0.22	0.24	0.25	0.20	0.19	0.21	0.18
4	2.36	2.10	2.40	2.05	1.98	1.97	2.02	2.00
5	0.56	0.53	0.58	0.50	0.41	0.42	0.47	0.47
6	1.83	2.30	2.41	2.58	1.27	1.60	1.29	1.35
7	-	-	-	-	0.59	0.55	0.54	0.51
8	0.46	0.51	0.45	0.41	0.29	0.32	0.31	0.32
9	0.17	0.14	0.16	0.18	0.10	0.08	0.10	0.09
10	1.76	1.81	1.70	1.59	1.22	1.43	1.20	1.15
11	1.67	1.45	1.67	1.57	1.15	1.17	1.17	1.13
12	0.79	0.67	0.72	0.65	0.43	0.45	0.49	0.52
13	0.03	0.08	0.05	0.05	0.03	0.04	0.03	0.05

3. Results

Table I summarizes the values found for the fast neutron dose equivalent per unit dose of x-rays at the center of each 20 x 20 cm^2 beam. The values range from 0.024 to 9.4 mSv Gy^{-1} depending on the energy and manufacturer of the accelerator. It should be noted that the neutron contamination at the beam center of the Siemens and Philip accelerators is lower by a factor of at least two as compared to the Varian and GE accelerators with similar Task Group-21 megavoltage values for x-ray beam. In Table II are shown the values of neutron dose equivalent measured in the patient planer per unit dose of x-ray at the isocenter. The Varian and GE patient plane values are a factor of two or more greater than the Siemens and Philips values except for the Siemens KD accelerator which had neutron leakage in the patient plane similar to the Varian 17.5 MV x-ray beam. This comparison of the neutron dose equivalent in the patient plane was based on similar Task

Group-21 megavoltage. The overall uncertainty associated with these measurements is of the order of ±20%.

4. Discussion and conclusions

In this work the neutron dose equivalent has been determined at the central axis of the x-ray beam and outside the beam in the patient plane for 13 different medical accelerators. The number of neutrons generated in the paraffin moderator due to photon interactions has been shown to be small[5] and corrections were not made to account for this effect. As a result of the low photon fluence in the patient plane corrections to account for photoneutron produced in the Bonner sphere moderator were not required.

The International Electrotechnical Commission(IEC) has proposed a maximum neutron dose limit in the patient plane of 0.5 mGy of neutrons per Gy of x-ray. This dose limit can be converted to dose equivalent by use of the quality factor for neutrons. The quality factor for neutrons varies from 2 to 10 depending on the neutron energy. Using a quality factor of 10 for fast neutrons yields a value of 5 mSv of neutrons per Gy of x-ray. As can be seen from Table II none of the accelerators exceed the IETC requirement for neutrons.

The neutron dose equivalent received by a 20 cm thick patient treated with parallel opposed 20 x 20 cm^2 beams to a dose of 50 Gy at mid-depth was estimated by use of the depth dose for a fission spectrum, the maximum beam central axis dose and depth dose values for the x-ray beam. A value of 0.30 Sv neutron dose equivalent was found for the GE 25 MeV accelerator based on this technique. Carrying out the calculation using the maximum patient plane dose 30 cm off the central axis one finds a dose equivalent of 0.090 Sv for the GE 25 MeV accelerator.

These dose equivalent levels do not seem excessive. However, there is at present a major interest in using intensity modulated radiation therapy(IMRT). When IMRT is conducted the dose equivalent outside the beam will be increased by a factor of 2 to 10 depending on the treatment system used. The probability of inducing new cancers when this modality is employed needs to be evaluated. Some possible solutions to this problem would be to add neutron shielding to the accelerator head and the use of lower energy x-ray beams(10-15 MV).

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The software program *Peridose* to calculate the fetal dose or dose to other critical structures outside the target area in radiation therapy.

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Abstract
An accurate estimate of the dose outside the target area is of utmost importance when pregnant patients have to undergo radiotherapy, something that occurs in every radiotherapy department once in a while. Such peripheral doses (PD) are also of interest for late effects risk estimations for doses to specific organs as well as estimations of dose to pacemakers. A software program *Peridose* is described to allow easy calculation of this peripheral dose.
The calculation is based on data from many publications on peripheral dose measurements, including those by the author.
Clinical measurements have shown that by using data averaged over many measurements and different machine types PDs can be estimated with an accuracy of ± 60% (2 standard deviatons).
The program allows easy and fairly accurate estimates of peripheral doses in patients. Further development to overcome some of the constraints and limitations is desirable. The use of average data is to be preferred if general applicability is to be maintained.

1. BACKGROUND AND PURPOSE

The incidence of cancer increases with age and as a consequence most patients entering a radiotherapy department are elderly. Nevertheless, this does not exclude the possibility of cancer occurring in younger people, at an age where they still have the prospect of establishing a family and having children. If young patients are treated with radiation it is essential that the dose to the gonads is kept as low as possible to keep the risks to the offspring at an acceptable level. Should pregnant patients be presented for radiation therapy and this therapy can not be postponed, keeping the dose to the fetus as low as possible is of utmost importance. Furthermore, there are times that conception occurs just prior to or during treatment. Knowledge of this dose at distances larger than a few centimeters outside the primary beam, which is called the peripheral dose (PD), is therefore essential in those cases. Computerised planning systems can accurately calculate the dose inside and at the edges of the primary beams; however, accurate dose calculations are usually limited to a few centimeters outside of the beam edges.
Determination of the peripheral dose has been the subject of extensive investigation, the results of which we have published previously [1-3]. In these papers data were presented for photon energies from cobalt-60 gamma radiation to 6, 10, and 23 MV x-rays. These values were derived from measurements of the contributions to the PD from radiation scattered in the patient, leakage radiation, and radiation scattered from the collimator. Our own data were combined with other published data [4] and were used to generate a generalized method to estimate the peripheral dose for any arbitrary field size or shape at different depths. In patients an accuracy of ± 60% (2 standard deviations) could be obtained [5]. In view of the uncertainty of known risk factors, we consider this accuracy acceptable.
On the basis of this generalized method we decided to develop a software program to perform these calculations automatically and to make this program available to the radiotherapy community.

2. STRUCTURE OF THE PROGRAM

The software is written in Delphi. Minimum system requirements are 4 MB RAM, 4 MB hard disk. It runs under Windows, version 3.11 and higher.
The data of our paper on a general applicable calculation method [4] form the basis for the calculation algorithm.
All graphical data from that paper are transformed into tabular data and intermediate values are determined by linear interpolation.
In figure 1 the input screen for one beam is presented showing also which input data are required. The maximum number of beams that can be calculated in one run is eight.

*Orthogonal beams:*In the first step the peripheral dose is calculated per beam as a percentage of the dose at depth of maximum dose (d_{max}) at a reference depth of 10 cm for a reference thickness of the patient of 20 cm. The equivalent square field size is used. A distinction is made between cobalt-60 gamma radiation and 4 to 25 MV photons.
The small variation of the PD for photon energies between 4 and 25 MV is accounted for by applying a correction factor in the second step.
Patient thickness is corrected for in the third step. When the primary beam travels through more tissue the contribution from patient scatter to the PD increases. The effect is greatest for small distances. Variation of the PD with depth is accounted for in the fourth calculation step. There are two opposite effects involved. Close to the beam the patient scatter contribution increases with depth as a result of the forward directed Compton scattering. On the other hand the contribution of leakage radiation and scattered radiation from the collimator, referred to as collimator related radiation (CRR), decreases with depth because of attenuation. This decrease roughly follows the percentage depth dose distribution of the primary photon energy. Far away from the beam the CRR is the sole source of radiation so the correction factor follows the primary beam attenuation.
In step five a correction is made to the PD if the CRR is intercepted by the couch. This might be the case for posterior-anterior beams for target volumes further away from the PD point, for instance when treating targets in the thorax or head and neck, with the PD point in the pelvic area. The CRR will then be attenuated by the couch.
In our calculation model, distance is defined as the distance of the PD point to the beam central ray, as opposed to some authors who use the distance to the beam edge. Consequently in our model field elongation can have a considerable influence. The PD point is much closer to the edge of an elongated fields with the long axis in the direction of the distance vector than with the long axis perpendicular to that vector. Especially at small distances this can make a considerable difference, again due to foreward directed Compton scattering. This correction is step six of the program.
Wedges in the beam have a large effect on the PD by the added amount of scattered radiation emanating from the wedge. This effect is largest for externally mounted wedges and smaller for internally mounted ones. Only few publications [6-8] deal with this issue and based on a combination of our own measurements and the published data, a global correction factor of 4 is used for external wedges and 1.5 for internal wedges in step seven.
In step eight the fraction of the PD contributed by the CRR is calculated. Again two sets of data are used, one for cobalt-60 gamma radiation and one for 4 to 25 MV photons, giving the fraction of the CRR as function of the field size and distance. Although this will vary between different collimator designs, it has been shown that this variation is not large [9].
For wedged fields the patient scatter contribution does not change so the increase of the PD is caused entirely by the increase of the scattered radiation from the wedge. This is also accounted for in this calculation step by including this scatter in the CRR fraction.
In step nine the influence of blocks is addressed. Published data [2-3,8] have shown that the PD does not change significantly when shielding is introduced in the beam. This can be explained by assuming that the reduction of the patient scatter contribution due to partly shielding the incident beam is counterbalanced by the increased scattered radiation from the shielding blocks and tray.
In the tenth step the CRR is corrected for attenuation at other depths, as described in the explanation of step four.

Tangential beams:
The program also offers the option to calculate the PD for tangential (breast) treatment techniques.
In this case the breast is the scattering volume and measurements were made for three breast sizes, which are called small, medium and large with field sizes to match. Interpolation by the program is based on the actual field size as stated by the user.
The program follows the same steps as for orthogonal fields with one exception. Since the patient scatter is determined by the breast size, there is no need for a correction for patient thickness. Furthermore, the depth of the PD point is defined differently. Since PD calculations in patients treated for breast cancer will often concern determination of the fetal dose, depth is now defined as the depth of the PD point (i.e., the fetus) in anterior-posterior direction

3. RESULTS

The results of the calculations are presented in a simple way (Fig. 1). At the bottom of the screen the results per beam are shown, subdivided in the PD and the CRR contribution both in cGy. At the top the combined results for all beams are shown.
The data and results can be saved as a file with default extension *.pdd* and a hard copy of the results can be printed.

Constraints and limitations
Certain constraints have to be considered.
An assumption is that the PD point is located more or less centrally and symmetrically in the body. Differences in the PD for deviations of the central position perpendicular to the plane through the beam axis and the distance vector of up to 5 cm are negligible; variations in distance and depth are accounted for.
The program cannot be used for other treatment modalities than photon beams. For electrons the scarce published data [10] and our own measurements indicate that the PD is roughly a factor of 4 lower, because there is hardly any scatter inside the patient and the CRR is much lower than for photons.
The program was not developed for use in intensity modulated radiation therapy (IMRT). During IMRT the number of monitor units delivered for a given target dose is much greater than in standard techniques. Consequently the contribution of CRR will be much greater but we are not aware of measurements on the exact magnitude of this contribution.
The program does not account for neutron production at higher photon energies. For 25 MV photons this can increase the PD by a factor 2.

Accuracy
We compared the calculations with clinical measurements and found a mean ratio of measured versus calculated PD of 0.92 with a standard deviation (SD) of 35% for all treatment techiques [5]. For tangential techniques only this was 1.12 and 26% respectively. We find it plausible that the program will be used most frequently for calculations in pregnant patients so the starting point of the program is an SD of 30%. The accuracy of the calculation is given as two SDs.
The accuracy of the calculation is largest for open beams with limited shielding. In case of the use of wedges the program uses some average correction factors for internal and external wedges. The accuracy of these factors, however, is estimated to be of the order of ± 30%. When the PD-point is located further away from the central axis of the beam, it is possible that the collimator-related radiation is intercepted by the treatment couch. In that case an attenuation factor is applied, based on our own measurements for our treatment couch. Data on the attenuation by couches from other manufacturers are not available.
The contribution of collimator-related radiation of linear accelerators to the PD is based on average data. However, some accelerators show higher collimator-related radiation values than others and there is also some dependence on collimator angle. The maximum difference is by a factor 2 [9]. For PD calculations at large distances, where the contribution is predominantly from collimator-related radiation, this can make some difference.

4. DISCUSSION

A software program has been developed which allows the easy calculation of the peripheral dose in patients who are treated with megavoltage photon radiation. Within its constraints and limitations it allows a fairly accurate estimate of the dose at any point in the body outside the treatment area.
Knowledge of the peripheral dose can help radiation oncologists in making important decisions in the treatment of cancer patients. Sometimes radiation therapy is the only viable treatment option when pregnant patients have to be treated and then it is of utmost importance to be able to estimate the risk to the fetus and compare this with the risk to the mother of postponing the treatment. Decisions on whether or not abortion should be considered may also depend on this information.
Another area where an estimate of the peripheral dose is of importance is in patients with pacemakers. Damage to pacemakers has been observed above 500 cGy [11] which is only a few percent of common clinical tumor doses. Assessment of doses to specific organs such as the thyroid may also be of interest to determine the possible risk of late effects such as carcinogenesis.

We feel that our program can be of great value for the professionals working in radiotherapy. We also feel that general applicability is desirable and therefore prefer the use of average data to the use of machine specific data, even at the cost of a small loss of accuracy. Situations where the PD has to be estimated are

rare and usually occur unexpectedly. A calculation model should then be readily available since there is no time to perform extensive measurements on leakage radiation and collimator scatter.

Note: The program can be obtained from the author, preferably by e-mail request.

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Radiation Protection of Staff and Patients During Fluoroscopic CT

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Abstract

CT fluoroscopy provides pseudo real-time cross sectional imaging and has been used in our clinic for biopsies, drainage and pain control. In the fluoroscopic configuration the radiologist stands in the room adjacent to the table as in conventional angiography. Because of concerns regarding staff and patient doses, measurements were made with standard CT phantoms to estimate doses.

It was found that as far as the patient is concerned, two minutes of CT Fluoroscopy gave the same effective dose as a standard abdomen CT exam. For the operator, the scattered dose decreases rapidly distal to the radiation plane and is 1 mGy per minute at 10 from the image plane. At the operator's chest at table side the dose rate was 0.5 mG per minute. This is about 5 times the dose rate at the side of the table during conventional angiography.

Operators must be careful not to leave their hands in the beam during fluoroscopy. The dose rates were 708 mGy and 272 mGy per minute for the head and abdomen respectively. ICRP exposure limits for the skin would therefore be exceeded for both studies in less than two minutes. Use of a specially designed syringe holder is recommended.

Background

Our existing CT Scanner(Toshiba Express SX) was recently updated to perform fluoroscopic CT. In this pseudo real-time mode eight 512x512 frames are displayed per second. For each progressive frame only one eighth of the data(or 45^0) is changed. All the other back projections remain the same facilitating fast computation. The scanner can operate up to 50 mA for a fluoroscopy time of 120 seconds. The fluoroscopy system appears just as a normal angiography suite with a footswitch and video monitor in the room. Because of the unusual procedure of the radiologist being in the CT scanner room with the patient during scanning, we have carried out some measurements to look at potential staff and patient doses.

Methods.

Measurements were performed with standard 16 and 32 cm diameter cylindrical acrylic dosimetry phantoms, using a Radcal model 9010 dosimeter with a uniform response 10 cm CT chamber. Scatter measurements were made with a Keithley 36150 radiation survey meter. Because the dose changes in the phantom on a cyclic basis, most measurements were made in the integral mode of operation.

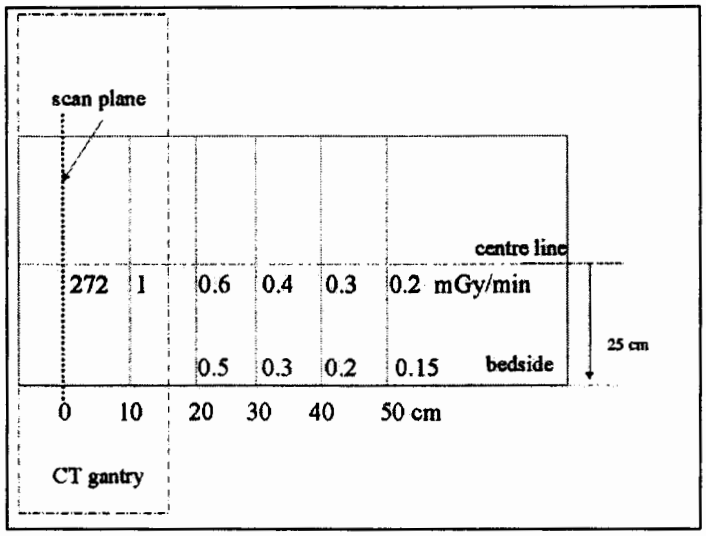
Patient Dose

Measurements made in the acrylic phantom were converted to patient effective dose by calculation of energy imparted to the phantom.
For normal single slice operation of the CT scanner for the abdomen at 120 kVp and 200 mAs the effective dose was 0.24 mSv per cm slice.
For fluoroscopic operation of the CT scanner for the abdomen at 120 kVp and 50 mA the effective dose was 3.56 mSv per minute. Two minutes of CT fluoroscopy therefore give an effective dose similar to a standard abdomen CT exam.

Dose to Operator's Hands

Directly in the x-ray beam on the surface of the abdomen phantom the dose is 272 mGy per minute. Likewise for the head phantom the dose rate is 708 mGy per minute. Clearly the dose in the direct x-ray beam precludes use while the hands are in the beam(the annual skin exposure limit would be exceeded after less than two minutes of CT fluoroscopy). These are air kerma doses. To convert to the operational quantity H(0.07) directional dose equivalent need to multiply by 1.26(40 keV effective energy - ICRU 47).

Radiation Scatter



Because of the highly collimated narrow x-ray beam, the scattered radiation decreases rapidly outside the actual beam. At 10 cm from the beam plane on the surface of the phantom the air kerma dose rate has dropped to 1 mGy per minute. At the operator's chest adjacent to the table, the air kerma dose rate is 0.5 mGy per minute. To convert to personal dose equivalent H(10) need to multiply by 1.17.This is roughly five times the dose rate at the side of the table during conventional angiography

Clinical Uses

For us the major uses so far for CT fluoroscopy have been 1.Biopsies: probably the most commonly used application 2. Drainage: Abscesses mostly, and again main advantage over US is visualizing the fluid collection deep in abdomen/pelvis, and ensuring safe pathway to access collection via percutaneous route (avoiding bowel, major vessels etc.), and 3. Much less commonly, injection of structures such as celiac plexus for pain control.

An Interactive Web-Based Radiation Protection Course in Fluoroscopy

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Abstract

The teaching of radiation protection to a large group of physicians, who are separated geographically and have complicated schedules, is a formidable problem. Therefore a web-based solution is attractive, allowing access to the material at any time and place. In this implementation the didactic material is presented in a web-based format. Subsequently, students attend a practical demonstration in one of the departments' fluoroscopy rooms.

Because of local experience with distance education, WebCT was chosen to present the material. WebCT(Web Course Tools)was developed by the University of British Columbia(UBC) to allow educators, with or without technical expertise, to create sophisticated web-base. Authors use a standard Web browser to create courses, and students use their browsers to access course material. WebCT provides a wide variety of tools and features that can be added to a course. Among the most useful tools used in this fluoroscopy course are the glossary, multiple-choice questions for each section, and a final test which is scored by the computer. As with all Web-based material the courses can be viewed in the traditional linear fashion or in any random way through the use of linkages.

Introduction

The World-Wide-Web Course Tools (WebCT) has been developed by UBC over the last few years and presents an environment that allows educators to create sophisticated web-based courses. These courses can incorporate a large number of tools and features. Furthermore, the interface to WebCT (the interface that is used by the educator to build a course) is entirely web-based. This has many advantages including simplicity and platform-independence. Using Web-CT requires that a course-author connect, using a browser such as Netscape, to a WebCT site. The site is simply an http server that serves the WebCT pages and CGI scripts.

What Does a WebCT "Course" Look Like?

The content of a course is provided by the course designer. Structure, interactivity, and educational tools are provided by WebCT. WebCT also allows the designer to alter the look of the course by, for example, selecting from existing (or creating custom) colour schemes, choosing between *formal* and *informal* button sets, incorporating custom or WebCT built-in banners, and so on.

Main Course Homepage and Tool Pages

A course developed using WebCT is organised around one main homepage. This homepage is the entry point for the course (the first page that designers and students see after having logged on to the course). It can contain, among other things, a banner image, a textual message, links to *course content elements* (notes and assignments, for example), and links to *course tools*.

While there is only one main homepage, there can be any number of subsidiary homepages (called *tool* pages). A tool page behaves exactly like the main homepage, except it is not reached immediately on entering the course. Instead, a tool page is reached by clicking an icon on the homepage, or another tool page. Thus the homepage and tool pages can form a hierarchy of pages with the main homepage as the root.

Course Content

WebCT provides a structure around which one can build a course. If you already have your notes in a word processor it is fairly straightforward to modify the material. The course needs to be broken into short sections, say two screens long, so that the students do not have to scroll too much. Each section is then saved in html format which is required for WebCT. Many word processors also convert images to GIF format. Otherwise the html editor in your word processor should allow you to incorporate links to other types of image format such as JPEG, which is most commonly used for x-ray images.

Once you have your course material in html format you can create a complete interactive course using only the tools provided by WebCT. When you log in to WebCT using a web browser(the system is optimised for Netscape) you can do so as the designer or as a student, naturally with different passwords. As a designer you have access to all designer facilities, such as file management, page design, on-line editing, indexing, glossary definitions, and a whole range of tools for student exams, marking and reporting.

Normally to create a course the files are uploaded using the file management facility, and then arranged in a suitable order or *path*. Each page in the course can then be customised to suit the author. Glossary terms to explain new terms can be useful, and multiple choice questions are easy to add. These MCQs are for self-assessment not final exams which are explained later. On any page an index term can be defined and this will be automatically integrated into the course index. Although this does not seem important initially, as the number of courses and pages grow an index becomes vital.

What is a Course Tool?

A course tool is a feature supplied by WebCT that can be incorporated into any course. Tools can be made accessible (through a clickable icon) from the main course homepage, tool pages, or from content page button bars. Examples of tools include a conferencing system, timed quiz delivery, on-line marking, grade storage and distribution, e-mail between course participants, searchable image archives (both shared and private to a course), student self-evaluation, student presentation areas (both individual and group), student annotation facility, student progress tracking, course glossary and index, and more.

Navigation

When students log on to the course, they are presented with the main home page. If they had ever been signed on before, WebCT can take them to the page of content they were at when they ended their previous session (using the "resume session" tool). Otherwise they can click on a path icon (perhaps the main set of notes), a tool page icon, or any other icon available on the homepage.

Once they are on a page of content, included in the button bar are navigation arrows that will take them to the previous or next page of notes in the path. If they ever stray off the path, perhaps to view an off-site URL, a single click returns them to the point from which they left the path. This avoids the reorientation otherwise necessary after a prolonged foray off the path. The navigation buttons also allow the student to go directly to the homepage, to retrace through the last few accesses, or to view the hierarchy of the current path for direct access to any page on that path. Also, the status bar at the bottom of the browser always displays the name of the path the student is on, and the page number currently being viewed.

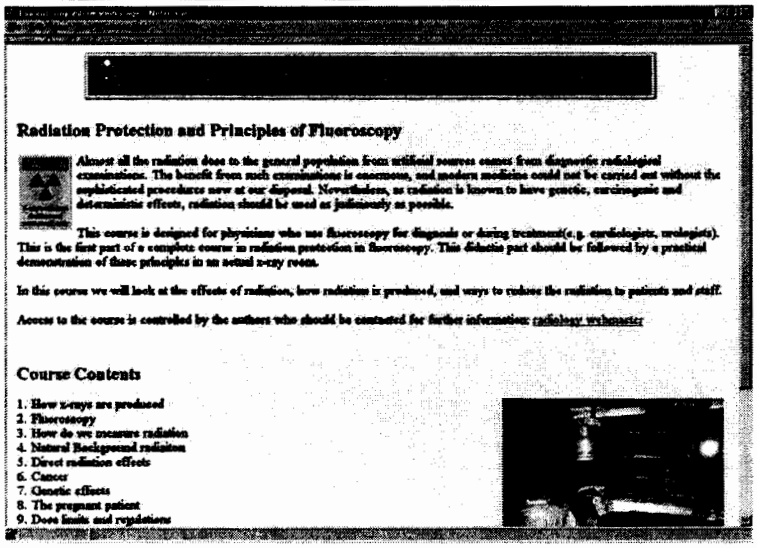
Finally, the button bar on each page of content provides direct access to any course tool that has been included on that page by the designer. These might include links to that page's multiple-choice questions, a link to a conference forum for that page of notes, or a link to reference material for that page.

Tests and Exams

On each page multiple choice type questions can be added to help the student understand the material. These questions are not used in the assessment of the student. Complete examinations can also be given via WebCT. Examination date, time and length are set on the system. Questions can be of many types. Multiple choice, true-false and simple word answers can be marked on-line. Short answer and essay type questions have to be marked by the examiner. The students can access their marks on-line.

Fluoroscopy Course

Typical screen captures from our fluoroscopy course are shown below.



Radiation Protection and Principles of Fluoroscopy

Almost all the radiation dose to the general population from artificial sources comes from diagnostic radiological examinations. The benefit from such examinations is enormous, and modern medicine could not be carried out without the sophisticated procedures now at our disposal. Nevertheless, as radiation is known to have genetic, carcinogenic and deterministic effects, radiation should be used as judiciously as possible.

This course is designed for physicians who use fluoroscopy for diagnosis or during treatment(e.g. cardiologists, urologists). This is the first part of a complete course in radiation protection in fluoroscopy. This didactic part should be followed by a practical demonstration of these principles in an actual x-ray room.

In this course we will look at the effects of radiation, how radiation is produced, and ways to reduce the radiation to patients and staff.

Access to the course is controlled by the authors who should be contacted for further information: radiology webmaster

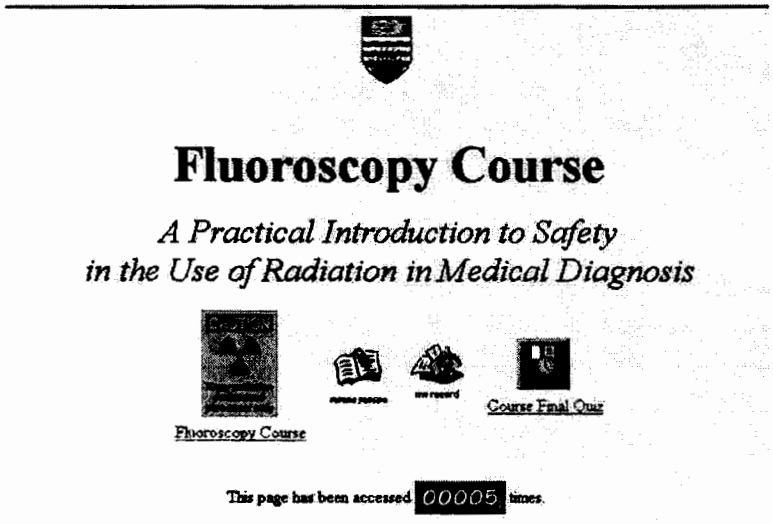
Course Contents

1. How x-rays are produced
2. Fluoroscopy
3. How do we measure radiation
4. Natural Background radiation
5. Direct radiation effects
6. Cancer
7. Genetic effects
8. The pregnant patient
9. Dose limits and regulations

The first screen is the page, which anyone can access on the internet, gives information about the course.

To log on students need an ID and password. This enables monitoring of student progress and identifies students who take the final test.

Next is the screen, which a student sees after logging onto the course.



Fluoroscopy Course

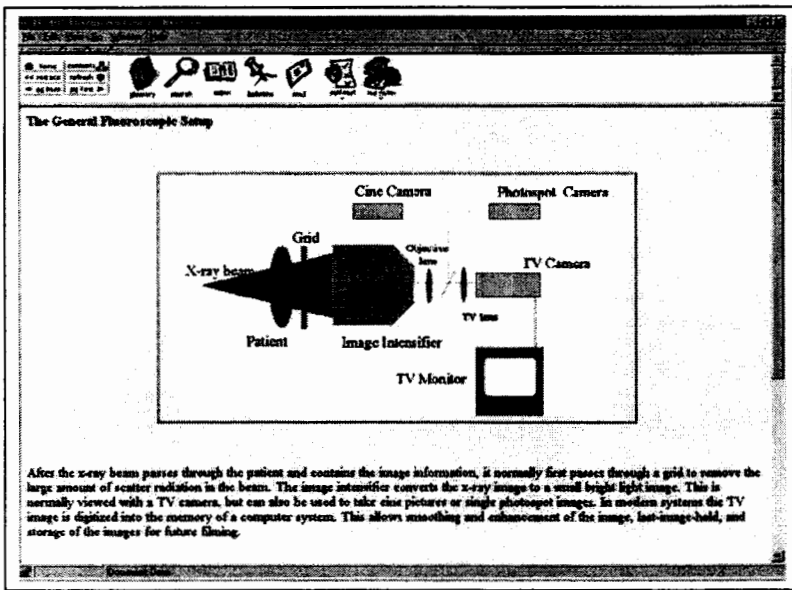
A Practical Introduction to Safety in the Use of Radiation in Medical Diagnosis

Fluoroscopy Course

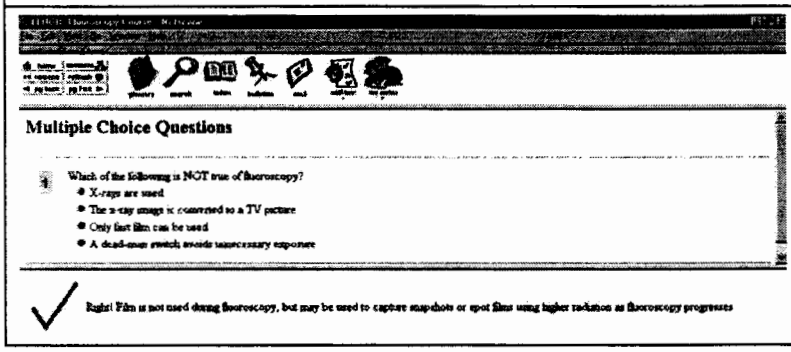
Course Final Quiz

This page has been accessed 00005 times.

From here the student can start the course or take the final test. At the beginning of each course a list of all the sections is seen as below. The counter can be reset at the start of each course to give an overall picture of student access. For the course instructor much more detailed information on what pages are read and for how long are available if necessary. As well as sometimes verifying that the material is actually read, this information can help to identify difficult sections of the course.



This shows a typical interactive page. The top bar shows the navigation tools, which enable the student to go through the course page by page or return to the contents page or the home page. Alongside the navigation tools are special tools which enable the student to access the glossary, index, bulletins from the instructor, mail from the instructor or other students, the self-test quiz, and private notes that the student can attach to any page. Terms in the glossary are highlighted in red in the text.



One of the questions from the self-test quiz for this page is shown at left. This question mode is designed for self-evaluation as the student progresses through the material.

By selecting any answer, correct or incorrect, feedback is given about the reasons for the answer.

We have also used WebCT as the basis of our undergraduate teaching modules in radiology. This is one of the most demanding areas of teaching because of the number and quality of diagnostic images needed. This distance learning package seems well accepted and suitable for instruction where geographic and scheduling constraints would impede normal lectures.

Further information can be found at our website at http://web.ucs.ubc.ca/aldrich/home.htm. and from http://www.webct.com

RADIATION SAFETY PROGRAM IN A HIGH DOSE RATE BRACHYTHERAPY FACILITY

by
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Teofilo M. Hermoso, MSc cand.***

Abstract

The use of remote afterloading equipment has been developed to improve radiation safety in the delivery of treatment in brachytherapy. Several accidents however, have been reported involving high dose-rate brachytherapy system. These events, together with the desire to address the concerns of radiation workers, and the anticipated adoption of the International Basic Safety Standards for Protection Against Ionizing Radiation (IAEA, 1996), radiation safety program have been developed at the Department of Radiotherapy, Jose Reyes Memorial Medical Center and at the Division of Radiation Oncology, St. Luke's Medical Center. The radiation safety program covers five major aspects: quality control/quality assurance, radiation monitoring, preventive maintenance, administrative measures and quality audit. Measures for evaluation of effectiveness of the program include decreased unnecessary exposures of patients and staff, improved accuracy in treatment delivery and increased department efficiency due to development of staff vigilance and decreased anxiety. The success in the implementation required the participation and cooperation of all the personnel involved in the procedures and the strong management support. This paper will discuss the radiation safety program for a high dose rate brachytherapy facility developed at these two institutes which may serve as a guideline for other hospitals intending to install a similar facility.

1. INTRODUCTION:

The use of radiation in treatment of patients is not devoid of risk. Experiences have shown that patients treated using radiation develop and manifest symptoms of side effects. Likewise, early radiation workers had developed radiation-induced cancers. This knowledge leads to the continuously work for the improvement of radiation safety of patients and personnel. The use of remote afterloading equipment has been developed to improve radiation safety in the delivery of treatment in brachytherapy. Several accidents however, have been reported involving high dose-rate brachytherapy system.

The Department of Radiotherapy of Jose R. Reyes Memorial Medical Center and the Radiation Oncology Division of St. Luke's Medical Center are two of the hospitals in the Philippines to first acquire remote afterloading systems. The development of a radiation safety program in these hospitals was started prior to the acquisition of the equipment. The foremost aim of the program is to improve the safety measures in the application of high dose rate brachytherapy, which will be of greatest benefits to patients and staff and at the same time to satisfy requirements of regulatory agencies.

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An effective radiation safety program will produce results such as decreased patient and staff unnecessary exposures, improved accuracy in the treatment and increased department efficiency, which will eventually lead to reduced overall operating costs. A well observed radiation safety program develops vigilance of staff as well as decreased personnel and management anxiety.

The guiding document in the preparation of the radiation safety program at the above mentioned hospitals has been the International Basic Safety Standards for Protection Against Ionizing Radiation (IBSS) (1).

This paper will discuss the radiation safety program for a high dose rate brachytherapy facility developed at the Department of Radiotherapy, Jose R. Reyes Memorial Medical Center and at St. Luke's Medical Center which may serve as an example for other hospitals intending to install a similar facility.

2. RADIATION SAFETY PROGRAM

The radiation safety program developed includes the following aspects: quality control and quality assurance, radiation monitoring, preventive maintenance, administrative measures, and quality audit.

2.1 QUALITY CONTROL/QUALITY ASSURANCE PROGRAM

The quality control/quality assurance (QC/QA) program [2] is conducted daily, monthly, every source-exchange. It consists of a set of mandated redundant performance checks, physical measurement, and guidelines for the development of performance procedures that are designed to minimize the frequency of human errors, miscommunication, and equipment malfunction. The quality control program is shown in Table 1.

Table1
BRACHYTHERAPY QUALITY ASSURANCE PROGRAM

Daily	Monthly	Quarterly
Keys/power switch	Source position accuracy	Source calibration
Printer operation	Test run for all channels	Indexer checks
Computer Display (date, time, decay factor)	Source calibration	Dummy and source drive checks
Treatment Indicators	Review of daily checks	Radiation survey
Door Interlocks	Radiation survey	Computer hardware tests
Emergency/Interrupt buttons		Check of safety features
Acoustic and light warning signals		
Stored source position check		
Patient monitoring system		
Survey meters		
Emergency safety containers		

The success of patient treatment in brachytherapy depends on accurate treatment delivery. Accurate delivery means that the intended radiation sources are delivered to their intended positions within the correct applicator and remain there for the correct time. The results of QC/QA tests has shown source position accuracy has been achieved to within 0.2 mm, and source calibration are within 3% of specified activity.

The daily quality control includes computer operations checks, date/time and decay factor check, and verification of safety aspects such as warning signs, door interlocks,

emergency buttons and patient monitor. These tests ensure that the patient is treated properly and that no person will be unnecessarily exposed to radiation by accident.

The monthly checks include source position accuracy, source calibration, and applicator integrity. A graph of the % difference between manufacturer specification and the clinically measured source activity for the last four installation is shown in Figure 1.

Quarterly checks are made to coincide with the source change and the preventive maintenance schedule.

Quality control checks are also conducted during treatment delivery process from the entry of the treatment parameters into the remote after loader to the delivery of treatment. These checks are carried out to validate the entered data, document the delivered treatment, and to immediately respond to unexpected machine malfunction and emergencies.

2.2 PREVENTIVE MAINTENANCE PROGRAM

The preventive maintenance program is based on the checks submitted by the service

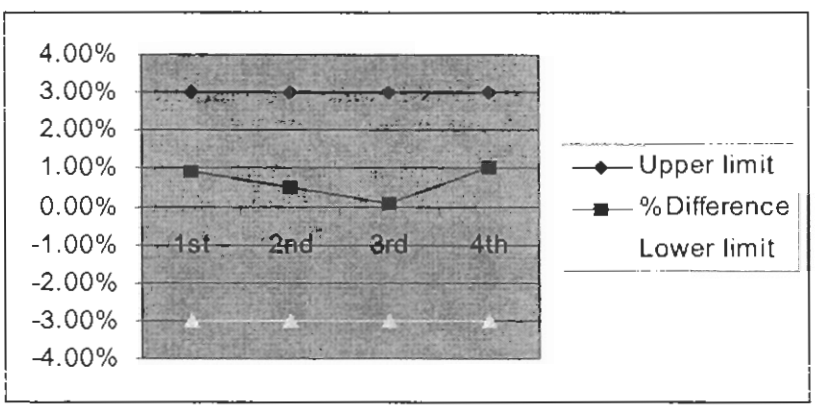

Figure 1 Source calibration accuracy

engineers of the supplier of the company. For every source change, mechanical checks, hardware tests as well as checks on the cycle counter, battery and electronic boards are performed. Values obtained should fall within the specifications and tolerance limits that are followed during the installation and commissioning process.

A list of parts to be replaced on regular basis such as battery and motor drives is provided by the manufacturer and is being followed.

2.3 ADMINISTRATIVE MEASURES

The head of the department is responsible for the overall departmental policy relating to quality matters and radiation safety program. He sees to it that his personnel are properly and adequately trained and that the radiation safety program is strictly observed. A medical radiation safety committee, having representatives from the different staff groups aside from the radiation health safety officer and management representative was formed to oversee this task. A forum is held quarterly where radiation workers and management study and discuss the radiation safety program in the department.

2.4. RADIATION MONITORING

Radiation monitoring has been used loosely to include activities referring to the source location, survey, inventory and status. Regular area surveys are conducted as part of

the radiation-monitoring program. Personnel exposures are monitored using film badges and pocket dosimeters.

Calibration of survey instruments is performed every six months. The cylindrical ion chamber, well chamber, together with their respective electrometer are conducted annually unless repair has been done in which case calibration must be performed prior to operation. Constancy checks is done on the dosemeter every month to confirm that results fall within 2%.

2.5 QUALITY AUDIT

The quality audit, involves internal and external aspects. The internal aspect includes medical, technical and procedural checks. The medical audit is performed by one of the consultants of the department through chart rounds, whereby charts of patients being treated are reviewed. The technical checks are conducted by the chief physicist to verify accuracy of source data and treatment plans. Procedural audit is conducted by the supervising radiologic technologist where spot checks are conducted to ensure that treatment protocol is carried out.

The external audit is conducted by the regulatory agencies, to include checks on the list of qualified users, inventory of sources and records and documentation of procedures.

It is recommended that an IAEA Postal Dose Inter-comparison be performed to be part of an external audit for brachytherapy since it has shown to be effective in highlighting problem areas and in improving quality for external beam radiotherapy worldwide.

3. RECEIPT AND TRANSPORT OF RADIOACTIVE SOURCE

Brachytherapy sources should be received by trained personnel and should be kept in a controlled and secured area. The type of radioactive source and the strength should agree with what was ordered. When opening the source packaging, it should be determined that there is no contamination present to damage during shipping and that proper documents, including return documents, are inside the shipping container. The spent source must be properly secured in the same way that it was received and all documents necessary for its transport back to manufacturer must be complete. The record for receipt and shipping out must be kept and maintained

4. RECORDS AND DOCUMENTATION

Records of the radiation safety procedures and the quality control tests results are necessary. Records of equipment performance are kept throughout equipment life to enable reconstruction of events in the future if required.

References

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[2] Rodriguez, L. et. al., Micro-Selectron HDR installation and quality assurance : Philippine experience, Selectron Brachytherapy Journal 7 (1993), pp. 16-18.

[3] CPR Part 14 Licenses for Brachytherapy Sources for Medical Use, Philippine Nuclear Research Institute, Diliman, Quezon City

RADIOLOGICAL PROTECTION OF PATIENTS BY RATIONALISATION OF X-RAY EXAMINATIONS IN A BIG HOSPITAL FROM BUCHAREST

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ABSTRACT

The aim of this study was to determine the possibilities of rationalization of medical exposure in order to obtain a patient dose reduction. A transversal observational study was conducted in an Occupational Medicine Dept, since 1997. A representative group of 499 patients was studied. A special attention was given to: number and type of x-ray procedures, frequencies and doses associated with some types of examinations, clinically unhelpful radiological investigation and the reasons of rejected and repeated films. A careful analyze of all these data and of the results lead to the conclusions that a large dose is advertable by: a valid clinical indication for all x-ray examinations, the dissemination to the medical staff of WHO Guidelines on referral criteria (1,2), using a proper x-ray equipment, using the alternative possibilities for investigation (endoscopy, magnetic resonance image). The success or the responsibilities of significant exposure-reduction efforts is the responsibility of the physician.

INTRODUCTION

Medical exposure is the highest source of man-made irradiation and it may be regarded as having two components: justified and unjustified exposure. Although, the doses usually received during the diagnostic procedures are small, a great number of exposures may induce a high radiation impact.

At the international level there is a great interest for establishing the radiation doses due to medical exposure. The goals of a radio-diagnosis service must be: a good quality image (!), the lowest possible cost, the shortest time required for fluoroscopic examination, the lowest possible dose incurred by both the operator and the patient. It is necessary to respect the basic principles in radioprotection: justification, optimization and reduction of dose (3,4,5). The optimal use of x-rays for medical diagnosis involve three distinct categories of activities: selection (the decision to request on x-ray examination for a particular patient), conduct (the appropriate performance of the requested examinations), interpretation (the analysis of the results) (5).

Unfortunately we can observe an over-utilization of radiological examinations with controversial or unknown medical indications (6).

Our transversal observational study, conducted in an Occupational Medicine Clinic, since 1997, tries to demonstrate some possibilities of rationalization of medical exposure in order to issue recommendations aiming at patient dose reduction.

MATERIAL AND METHODS

This study was conducted in an Occupational Medicine Clinic in Bucharest. General data about clinic in the survey are: Occupational Medicine dept., 70 beds, about 7100 x-ray examinations per year for about 2000 admitted patients per year. Data collection was performed using the clinical records from observation files, for 499 admitted patients: the patient individual data –sex, age, profession, type and exposure time of exposure to professional risks, diagnosis, type and number of x-ray procedures, technical reasons of rejected and repeated films, conclusions concerning the medical justification of radiological examinations. Among the patients investigated there were 48.5% female and 51.5% male. The average age was 44.05+/-8.5 years old (active population). 88% of admitted patients were between 31 and 50 years old (active population). The main diagnosis for admission in the clinic were represented by asthma (187), pneumoconiosis (168), chronic bronchitis (56), occupational poisoning (63), others (25).

The conventional x-ray equipment used within the clinic is TUR-D-700 type, made in 1968, with the maximum settings: 120 kV and 700 mAs, and two possibilities for x-ray examination – radiography and fluoroscopy, no TV amplifier. The parameters used for routine x-ray examinations are in the table no.1.

Table no.1. Parameters for routine X-ray examinations in the radiology dept. of Occupational Medicine Clinic

TYPE OF PROCEDURE	kV	mAs
CHEST PA	58-65	0.2
CHEST LAT	68-72	0.5 –0.8
CHEST OBLIQUE	70-75	0.5 – 0.8
CHEST TOMOGRAPHY	68-72	3
LUMBAR SPINE AP	60	0.5
LUMBAR SPINE LAT	80-90	2
PARANASAL SINUSES	70	1

The effective doses from Table no.2 are obtained from the measured of dose-area product ($Gy.cm^2$) and of entrance surface dose (mGy), by application of appropriate conversion factors from NRPB, UK (7). The last column of the table is for the local calculated effective dose (in mSv). We did not calculate the values for paranasal sinuses and chest tomography, so we used the national calculated doses.

Table no.2. Diagnostic X-ray examinations

a. FLUOROSCOPY

PROCEDURE	DOSE-AREA PRODUCT ($Gy.cm^2$)	EFECTIVE DOSE (NATIONAL) (mSv)	EFECTIVE DOSE (LOCAL) (mSv)
CHEST FLUOROSCOPY	13.0	0.95	1.3
BARIUM MEAL	21.0	4.10	4.20

b. RADIOGRAPHY

ORGAN AND PROJECTION	ENTRANCE SURFACE DOSE (mGy)	EFECTIVE DOSE (NATIONAL) (mSv)	EFECTIVE DOSE (LOCAL) (mSv)
CHEST			
- PA	1.0	0.10	0.10
- LAT	1.9	0.15	0.15
- SUB-TOTAL	-	0.25	0.25
- OBLIQUE	-	0.20	0.20
- TOMOGRAPHY	-	2.8	2.8
LUMBAR SPINE			
- AP	9.4	1.00	1.00
- LAT	10.0	1.93	2.50
- SUB-TOTAL	-	2.93	3.50
PARANASAL SINUSES – PA	8.6	0.069	0.069

Both the frequency and the doses associated with some types of x-ray examinations were investigated (chest fluoroscopy, barium meal, chest – postero-anterior=PA, lateral=LAT, oblique projections and standard chest tomography, lumbar spine antero-posterior=AP and lateral=LAT projection).

RESULTS

The total number of x-ray examinations for the studied group was 2041. The number of radiological investigation per patient was between 1 and 15, with an average 4.1+/-2.2 different procedures: 1 patient with 15 procedures, 2 with 14, 1 with 13, 3 with 12, 6 with 11, 3 with 10, 15 with 9, 16 with 8, 32 with 7, 49 with 6, 99 with 5, 53 with 4, 62 with 3, 55 with 2 and 69 patients with only one radiological procedure. This situation reflects an over-investigation of some patients and includes the repeated procedures.
Regarding the types of radiological procedures of interest of our study, the situation is illustrated in table no.3.

Table no. 3. – Number of each type of radiological procedures

TYPE OF PROCEDURE	NUMBER OF PROCEDURES
BARIUM MEAL	94
CHEST FLUOROSCOPY	128
CHEST RADIOGRAPHY PA	261
CHEST RADIOGRAPHY LAT	4
CHEST RADIOGRAPHY OBLIQUE	12
CHEST TOMOGRAPHY	40
PARANASAL SINUSES	149
LOMBAR SPINE	281

Barium meal was frequently utilized as in the hospital there are available only two fibre-optic endoscopy laboratories, and because the clinicians decided to investigate all the patients with minimal gastric complaints (burns, pain). We can consider this decision as a source of over-utilization, which certainly leads to an increase of patient dose.

It is well known that chest fluoroscopy has a very limited use; it cannot replace chest radiography and produces a much higher patient dose and much lower information. Chest fluoroscopy was used because the hospital has had some economical problems in getting radiological films. In connection with barium meal investigation, 71 chest fluoroscopy were performed.

The number of chest radiography is justified by the specific of the clinic (187 asthma, 168 pneumoconiosis and 56 chronic bronchitis), but a potential dose reduction method could be the using of the radiological films performed in other medical centers.

In this time we know the high level of exposure and the limits of conventional chest tomography. The clinicians were obliged to recommend this x-ray procedure because we have only few computed tomographs in Bucharest. From radiation protection point of view we can consider the doses received by this examination (with a total of 112 mSv) as mostly unnecessary.

We observe that 32% from 281 radiological examinations of lumbar spine (antero-posterior and lateral projection) were performed to patients under 40 years old, without an orthopedic examination or significant clinical signs, considering only the complaints of the patients.

From 149 paranasal sinuses radiological investigation, only 50 were performed under an ORL examination. For 61 patients the ORL examination was performed after x-ray exposure. Unfortunately only for 52 patient we obtain the diagnosis of sinusitis. Usually, in case of asthma, our clinical practitioners ask for this kind of x-ray investigation, in order to find a source of infection.

A large number of x-ray examinations were repeated when the image quality appeared unsatisfactory at the first attempt. We observe the following data regarding rejected and repeated radiological films (table no.4).

Table no.4 – Number and reasons for spoilt films

PROCEDURE	TECHNICAL REASONS FOR SPOILT FILMS							
	1	2	3	4	5	6	7	TOTAL
BARIUM MEAL		1						1
LUMBAR SPINE	1		1	1	2	2	1	8

CHEST RADIOGRAPHY PA	7	10	8	1	4	6	5	41

(1 – positioning, 2- motion, 3- under or over-exposure, 4- improper developing techniques, 5- film artifacts, 6- processor, 7- others).

All these repeated exposures may be also considered as unnecessary medical exposure. The total effective dose received in our study group, by repetition of examination was 36,3 mSv.

CONCLUSIONS

The results of our study testify the potential for a significant reduction in patient dose received during the medical exposure. The unnecessary medical irradiation arises from unjustified and/or unoptimized x-ray examinations. There was a little justification for many radiological examinations. The principal possibilities for dose reduction, pointed out by our research, were:

- to eliminate clinically unhelpful examinations; it is essential that there should be a valid clinical indication for all x-ray investigation and a correct selection of type of exposure for a particular patient, the number of radiological exposure must be kept to a minimum consistent with obtaining the necessary diagnostic information (according to WHO guidelines, ref. No.1, 2);
- to reduce repeat rate;
- to collect the rejected films in order to analyze them and to take corrective measures;
- to reduce number of films per examination;
- to reduce the number of fluoroscopies (both for chest and barium meal) and to reduce time of fluoroscopic investigation;
- to use a proper x-ray equipment to produce an image of standard quality;
- to operate optimally film processor;
- to use alternative methods for diagnosis;

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Patient's dose assessment during sinus X-rays radiography at « hôpital du Point G »

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Objective:
- To evaluate the patients X-rays dose during head radiography for sinusitis
- To precise the influence of source-image distance on the patient's dose.

Material and method :
From may 1997 to january 1999, 83 patients with clinical suspicious sinusitis have been included in this study. Skull radiography in 3 positions (posterior, lateral and Blondeau view) have been achieved for each patient on 24x30 centimeters size films. These radiography were realised on a Diagnost 7 Masio Philip X-rays machine. Three TLD dosimeters were pasted against every patient target organs (thyroid, rigth and left eyes). The source-image distance (SID) was 100 centimeters for the first group (35 patients) and 125 centimeters for the second group (48 patients). The selected parameters (high voltage and charge) were as follow:
Skull postero-anterior view: 65 to 85 kV, 80 mAs
Skull lateral view: 60 to 75 kV, 80 mAs
Blondeau view (paranasal sinuses): 90 to 95 kV, 100 mAs.

Results :
All the radiographies were analysed by the same radiologist who didn't know the SID. All the films were of good quality. The patient's dose in millisievert for each target organ were:

	Left eye	Right eye	Thyroid
Group I (SID = 100 cm)	3,2 (+ ou – 0,66)	3, 0 (+ ou – 0,82)	0,62 (+ ou – 0,09)
Group II (SID = 125 cm)	1,9 (+ ou – 0,48)	1, 86 (+ ou – 0,50)	0,39 (+ ou – 0,08)

In conclusion, the increase of SID from 100 to 125 centimeters allows patient's dose reduction by a factor of 1.6 without the alteration of the films quality, hence the reliability of the diagnosis.

Key words: Sinus radiography, Patient's dose, Dosimetry.

Patient's dose assessment during sinus X-rays radiography at « hôpital du Point G »

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1. Introduction:

Radiation doses from radiodiagnostic radiology are the largest contribution to the collective dose from all man-made sources of radiations. In Mali (west africa), where the radiation protection law instead International Atomic Energy Agency (IAEA) effort is still on draft form, the number of X-rays diagnostic installations grows year by year. If 86% of these installations are a second-hand machines, most of them are at least 20 years old (Sidibé *et al.*, 1995). Also any project on dose assessment and developping dose reference levels and image quality criteria for common diagnostic examination have been running. In « hôpital du Point G », skull radiography is the second largest examination just after chest radiography, and sinusitis is the mainly reason of such radiography. If it is well recognised that the over-zealous reductions in patient doses can have deleterious effects on the diagnostic information of the image, in some cases, doses reduction can even be obtained together with an improvement of the image. In this fact our present study have been done with following purposes:

- To evaluate the patients X-rays dose during head radiography for sinusitis ;
- To precise the influence of source-image distance on the patient's dose.

2. Material and methods:

From may 1997 to january 1999, 83 patients with a clinical suspicious sinusitis were included in this study. These patients included 36 males and 47 females. The mean age of our study population was 28 years (average: 5 to 67 years). All the radiographic examiantions were realised according to the physician recommendation through following projections: skull postero-anterior, lateral and Blondeau views. Radiography were realised on a Diagnost 7 Massio Philip X-rays machine with a 24x30 centimeters size films (Kodak X-Omat K film). Patients were divided in two groups according to the Source – Image – Distance (SID) which was 100 centimeters for group I (35 patients) and 125 centimeters for group II (48 patients). For patient doses evaluation we used 3 previous calibrated thermoluminescent dosimeters (TLD). These TLD were pasted for each patient on thyroid, right and left eyes. These organs were selected because they are target organs for each view. The selected constant parameter (high voltage and charge) for X-rays radiography were as follow:

Skull postero-anterior view: 65 to 85 kV, 80 mAs
Skull lateral view: 60 to 75 kV, 80 mAs
Blondeau view: 90 to 95 kV, 100 mAs.

All the films were transported through the same processing sequence (developing, fixing, washing and drying) of an automated processor. Each picture was closly identified and evaluation of all pictures have been done by the same radiographer without information on the SID parameter. For image quality assessment we used a qualitative rating with 3 scales (Poor, Satisfactory, Good) for each picture.

3. Results:

The criteria for image quality assessment were:
Skull postero-anterior view:
- symetrical reproduction of the skull;
- symetrical reproduction of rock face on the lower part of the orbits;
- repoduction of spongiosa and corticalis;
- visualization of the skull sutures.

Skull lateral view:
- visualization of the skull sutures;
- superimposition (left-right) of the orbits roof;
- visualization of the skull and neck junction.

Blodeau view:
- symetrical reproduction of face;
- visualization of maxillary sinus;
- visualization of the rock under maxillary sinus.

Table I, II, and III represented the summary of these criteria , and table IV represented patient's doses in millisivert.

Table I: Image quality assessment according to a qualitative 3 scales (skull postero-anterior view)

	Poor	Satisfactory	Good
Group I (SID = 100 cm)	0	9	26
Group II (SID = 125 cm)	0	12	36

Table II: Image quality assessment according to a qualitative 3 scales (skull lateral view)

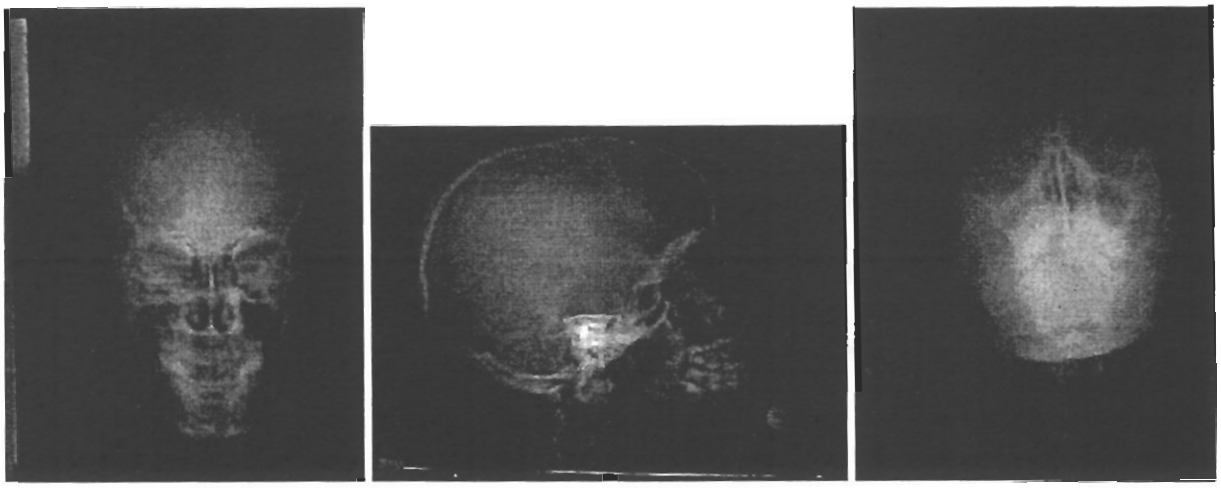
	Poor	Satisfactory	Good
Group I (SID = 100 cm)	1	15	20
Group II (SID = 125 cm)	0	21	27

Table III: Image quality assessment according to a qualitative 3 scales (Blondeau view)

	Poor	Satisfactory	Good
Group I (SID = 100 cm)	3	12	21
Group II (SID = 125 cm)	4	18	26

Table IV: The patient's dose in millisievert for each target organ were

	Left eye	Right eye	Thyroid
Group I (SID = 100 cm)	3,2 (+ ou – 0,66)	3, 0 (+ ou – 0,82)	0,62 (+ ou – 0,09)
Group II (SID = 125 cm)	1,9 (+ ou – 0,48)	1, 86 (+ ou – 0,50)	0,39 (+ ou – 0,08)

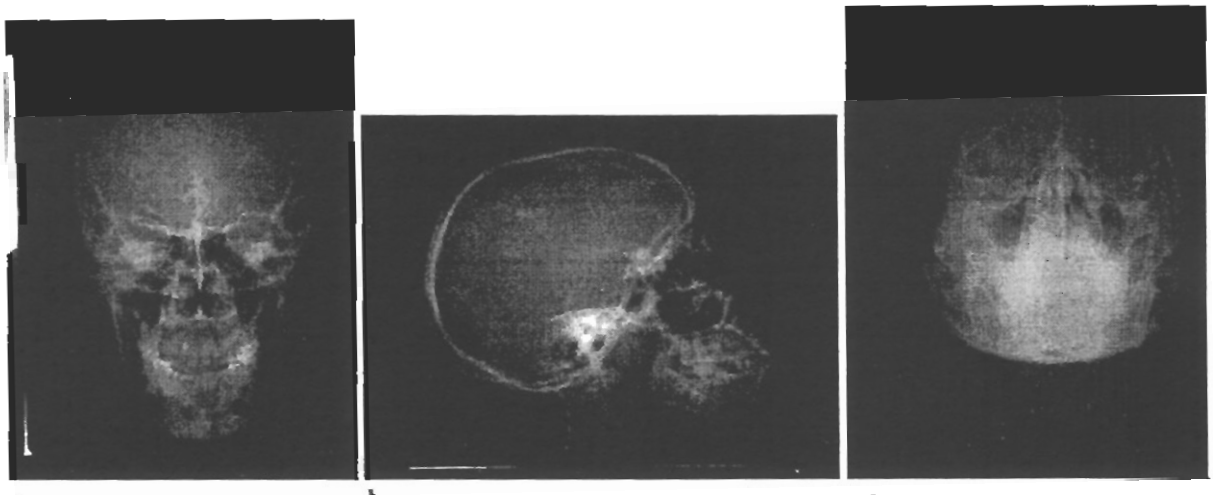


a b c

Picture 1: X-ray radiography at SID 100 centimeters:

a) skull postero-anterior view;
b) skull lateral view;
c) Paranasal sinuses (Blondeau view).

RIGHT MAXILLARY SINUSITIS



a b c

Picture 2: X-ray radiography at SID 125 centimeters:

a) skull postero-anterior view;
b) skull lateral view;
c) Paranasal sinuses (Blondeau view).

NORMAL MAXILLARY, FRONTAL AND SPHENOIDAL SINUSES

In conclusion, the increase of SID from 100 to 125 centimeters allows patient's dose reduction by a factor of 1.6 without the alteration of the films quality, hence the reliability of the diagnosis.
According to the situation of the situation of X-rays equipment in Mali, a national project of dose assessment and developping dose reference levels and image quality is necessary.

Key words : Sinus radiography, Patient's dose, Dosimetry.

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Need for harmonisation in the establishment and use of reference dose levels in radiology

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Abstract

Surveys of patient dose in diagnostic radiology revealed a wide variation in doses to patients for the same types of x-ray examination. The large dose variations found in the surveys focussed the attention to possibilities for dose reduction in diagnostic radiology. Reference doses were proposed to foster the elimination of doses at the high end of the distributions. Different proposals concerning the establishment and use of reference dose levels (RDLs) have been made by international organisations involved in radiological protection. In practice the diversity of approaches concerning RDLs is even larger. It is concluded that there is need for harmonisation.

1. Introduction

Surveys of patient dose in diagnostic radiology in the 1950s in the UK [1], in the 1970s in the USA [2], in the 1980s in English hospitals [3] and in 1991 in Europe [4] revealed a wide variation in doses to patients for the same types of x-ray examination. The large dose variations found in the surveys focussed the attention to possibilities for dose reduction in diagnostic radiology. Reference doses [5,4] were proposed to foster the elimination of doses at the high end of the distributions.

The International Commission on Radiological Protection (ICRP) [6] recommends the use of diagnostic reference levels (DRLs). For diagnostic radiology, the ICRP states that 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 a representative patient. In practice, DRLs can initially be selected as a percentile point on the observed distribution of doses to patients. Finally, the ICRP [6] recommends that the values should be selected by professional medical bodies, be reviewed at suitable intervals and be specific to a country or region.

The International Atomic Energy Agency (IAEA) [7] introduced the term guidance level as a level of a specified quantity above which appropriate actions should be considered. The guidance levels are intended to be a reasonable indication of doses for average sized patients. They are to be established by relevant professional bodies in consultation with the regulatory authority following the guidance levels given by the IAEA [7]. The levels are intended to provide guidance on what is achievable with current good practice rather than on what should be considered optimum performance. The guidance levels are to be applied with flexibility to allow higher exposures if these are indicated by sound clinical judgement and to be revised as technology and techniques improve.

In the Medical Exposure Directive (MED) [8] it is stated that Member States of the European Union shall promote the establishment and use of DRLs for radiodiagnostic examinations, and the availability of guidance for this purpose having regard to European DRLs where available.

In the present contribution the various approaches followed for the establishment and use of reference dose levels are discussed

2. Dose Surveys and the Establishment of Diagnostic Reference Levels

Based on the national survey of doses to patients undergoing a selection of routine X-ray examinations in English hospitals [3], national reference dose levels have been established in the UK [5] for standard adult patients. They are obtained as rounded third quartile values of the mean hospital dose distribution, in terms of entrance surface air kerma (including backscatter). Similarly, reference values were established for more complex examinations in terms of air kerma-area product.

In European Guidelines [4,9] reference levels were obtained from European dose surveys for adult and paediatric patients, as rounded third quartile values. Reference dose values for mammography using a 4.5 cm thick polymethylmethacrylate (PMMA) phantom are presented in Ref. [10] as a function of optical density on the mammogram. For CT [11] reference levels are proposed for routine examinations in terms of weighted CT dose index [11] and in terms of dose length product [11]. The reference values again correspond to rounded third quartile values from dose surveys using standard head and body CT dosimetry phantoms.

As the MED [8] has to be implemented in the national legislation of the EU Member States and in practice, various proposals for reference dose levels have been published, (to be) based on dose surveys. A summary of proposals presented during a workshop entitled "Reference Doses and Quality in Medical Imaging" held in Luxembourg in 1997 is given in Table I. In addition, proposals for local reference dose levels were presented during this workshop.

TABLE I. SUMMARY OF PROPOSALS FOR REFERENCE DOSE LEVELS PRESENTED DURING A WORKSHOP HELD IN LUXEMBOURG IN 1997

Country	Reference	Quantities[a]	Concept
Germany	[12]	$K_{a,e}$, $K_{a,i}$, KAP, DLP	Various including, 3rd quartile
Germany	[13]	$K_{a,i}$, $K_{a,A}$,, E_{Fluor}	3rd quartile
Netherlands	[14]	$\underline{K}_{a,e}$ rate (fluoroscopy)	3rd quartile
Netherlands	[15]	E, $K_{a,i}$, KAP	3rd quartile
Sweden	[16]	D_G	Reference (target) levels
Nordic	[17]	$K_{a,e}$, KAP	Guidance levels

[a] $K_{a,e}$ is entrance surface air kerma (including backscatter), $K_{a,i}$ incident air kerma (not including backscatter), KAP air kerma-area product, E_{Fluor} effective dose due to fluoroscopy, E effective dose and D_G mean glandular dose.

3. Discussion of various aspects related to reference dose levels

3.1. Dosimetric quantities

The dosimetric quantities indicated in Table I are not all easily measurable, as proposed by the ICRP. In Refs. [13,15] RDLs are expressed (also) in terms of effective dose and in Ref. [16] target doses for mammography are given in terms of mean glandular dose. Therefore, in this paper the term reference dose level (RDL) is used instead of DRL.

The dosimetric quantities for specification RDLs are usually $K_{a,i}$ $K_{a,e}$ or KAP. The use of these quantities has as a restriction that they are relevant for patient dose only when the techniques (x-ray spectrum, field size etc.) and patient dimensions are approximately constant. Otherwise the use of effective dose will be more appropriate, or RDLs should be established in dependence on the techniques applied and patient dimensions.

3.2. Selection of reference dose level from results of dose surveys

Not all the proposals are following the concept of using third quartile values of widespread surveys as the basis for selection of a reference dose level. The concepts used are not always apparent but some proposals appear to be redefining the purpose of RDLs into a guide to optimum performance or minimum achievable doses compatible with the diagnostic need (guidance levels or target levels in Table I).

3.3. Status of the proposals

According to the ICRP [6] professional medical bodies should select DRLs. According to the IAEA [7] guidance levels are to be established by relevant professional bodies in consultation with the regulatory authority following the guidance levels given by the IAEA. In the MED [8], Member States shall promote the establishment and the use of DRLs, and the availability of guidance for this purpose having regard to European DRLs where available.

In the UK national RDLs are established by relevant professional bodies [5], but not in (formal) consultation with the regulatory authority. The status of the recommendations of the recent proposals (Table I) is less clear and also differ from recommendations in Refs. [6-8]. The German proposal in Ref. [12] has been made by the Federal Office for Radiation Protection in consultation with an expert group of physicians and medical physicists. The recommendations presented in Refs. {13-15} are of scientific value but do not have any official status. The target dose levels for mammography [16] and the Nordic guidance levels [17] are published by national radiation protection authorities.

In practice, it might be preferable to establish national RDLs by professional bodies (national societies of radiologists, medical physics experts and radiographers) jointly with regulatory authorities. Regional or local professionals might establish regional or local RDLs, at lower values than the national levels, if available.

3.4. Differences in procedures

When RDLs are exceeded, it should be noted that the complexity of the procedure might be different from that for which the RDL was established. RDLs could also be exceeded for particularly large patients, unless patient size is taken into account in the RDL. For complex procedures, e.g. in interventional radiology it might be difficult to establish RDLs unless some classification of the complexity of the procedure is provided. Furthermore, it should be stressed that RDLs are aimed at patient dose reduction but the required diagnostic information is also of major importance. This means that in individual cases, the exceeding of RDLs will be justified when the required diagnostic information is essential for patient treatment.

3.5 Measurements with patients or phantoms

The ICRP [6] indicates that a simple standard phantom or a representative patient can be applied to establish or use a DRL. When a phantom is used it should be made sure that it is representative for the average patient. The use of a phantom does not provide information on the influence of variations in patient dimensions on patient dose. The advantage of the use of a phantom is that the number of measurements is smaller than that in the case of measurements with patients.

Measurements with patients have as advantages that the influence of variations in patient dimensions on patient dose are obtained and that there is no need to design and construct representative phantoms. Sometimes only a selection of patients is used for establishing RDLs. This is an approximation of the representative patient mentioned by the ICRP [6]. However, in this way the dose variations will be underestimated. When measurements are made with patients the selection criteria, e.g. size and sex should be specified.

3.6. Corrective actions

The corrective actions to be undertaken when a RDL is systematically exceeded should be specified, including procedures of continuing use under special circumstances.

4. Benefits achieved by using national RDLs

Periodic monitoring of patient doses employing the UK national protocol [5] has become widespread in the UK. A review of 1995 [18] showed that by then only about 10 percent of the hospitals exceeded the reference doses for common conventional x-ray examinations. The mean and

third quartile values of the dose distributions had dropped by about 30 percent since the national survey in the 1980s [3].

4. Conclusion

RDLs are a valuable tool to achieve patient dose reduction. However, the different approaches met in practice clearly indicate a need for harmonisation.

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CN-85/16

FORM B
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INTERNATIONAL CONFERENCE ON THE RADIOLOGICAL PROTECTION OF PATIENTS

in

- **Diagnostic and Interventional Radiology**
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HIGH DOSE AND LOW DOSE RADIATION EXPOSURE IN THE INDUCTION OF BREAST CANCER

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Abstract.

In today's modern practice of Radiation Oncology it is becoming increasingly common to follow many patients with breast cancer. There is a proven association between prior radiation and the development of breast cancer, although in many instances the available sources of data are confusing.

Characteristic features of radiation induced breast cancer are the importance of age at first exposure to radiation and the long latency period. The risk of breast cancer is highest in women exposed in the first decade of life and lessens progressively with increased age at exposure. The latency period is typically 10 years or more; a time in which other age dependent factors may influence the expression of the malignant phenotype. Genetic factors may also (in theory) increase a particular patient's susceptibility.

Introduction and Status of the Art.

1. LOW DOSE RADIATION AND BREAST CANCER

There are many reports in the literature addressing the potential role of mantle irradiation and the development of breast cancer. It has been well established that ionizing radiation can be a carcinogen for breast cancer. The available data demonstrate that this risk decreases with increasing age at exposure. There are several sources of data, but the results of these studies are sometimes contradictory.

1.1. DATA ON ATOMIC BOMB SURVIVORS

The sensitivity of the breast tissue to ionizing radiation has been amply demonstrated by epidemiological studies in Japanese Atomic Bomb survivors[1,2]. There are several reports in the literature like the Life Span Study sample demonstrating an increased incidence of breast cancer in this population. There is a strong linear radiation dose response, with the highest dose-specific excess of relative risk among survivors under 20 years at the time of the blast, and much higher for patients exposed during infancy. The cancer excess appears to be confined mainly to the group of women exposed before 40 years of age. A marginally significant trend was seen among women exposed at 40 years or older.

There is a much weaker association between dose and the prevalence of non-proliferative and proliferative breast disease. There are some interesting autopsy studies in survivors of the Atomic Explosions. These studies have been reported by Tokunaga [3] on 225 patients who received low dose radiation (0.2 Gy kerma), and 88 who achieved high dose radiation (1 Gy kerma or more). 81% of the Low dose breasts and 74% of the High dose breasts has one or more non-proliferative lesions, with an statistically significant relationship with dose.

Proliferative disease, and atypical hyperplasia in particular, was also elevated in both groups, (16% Vs 11%), also with a statistically significant relationship with dose.
Evidence for non-proliferative and in particular proliferative disease is strongest for the group of ages 40-49 at the time of the explosion.

1.2. OCCUPATIONAL EXPOSURE TO IONIZING RADIATION

The risk of breast cancer among female radiological technologists has been studied, in a population of 105,000 female radiation workers between 1926-90, including Radiation therapy technologists, dental X Ray Technologists, fluoroscopy, routine X rays, etc. [4]. The authors used the American Registry of Radiological Technologists, designing a case control study. Breast cancer was not significantly increased with occupational exposure in any of these procedures. there was also no relationship between risk and number of years worked [5-7]. Studies in Denmark yield comparable results [8].

1.3. DIAGNOSTIC EXPOSURE TO IONIZING RADIATION

There is a controversy about the role of mammograms and radiation induced breast cancer. It is important to know that an average woman who is screened with mammograms each year for 30 years, beginning at age 40 will have her breast exposed to a total dose of less than 0.1 Gy. The incidence of breast cancer in female patient with tuberculosis examined with fluoroscopy after therapeutic pneumothorax in Massachusetts among 5000 women between 1925 and 1954 [9]. Average number of examinations was 88. Increased rates of breast cancer were not apparent until about 10-15 years after the initial fluoroscopy examination. The excess risk then remained high trough all intervals of follow up, up to 50 yr. after the first exposure. Age at exposure strongly influenced the risk, with young women, below 40 at highest risk. (RR 1.06), particularly those between 15-24 yr. The estimated mean radiation to the breast was 79 cGy. There was a strong linear relationship between dose and risk of breast cancer. Danish researchers found similar results in a case-control fluoroscopy study [10].

A scientific publication in 1995 described a family with a cluster of breast cancer cases occurring in a generation, and their relationship with repeated fluoroscopic examination during early childhood and adolescence [11]. The development of breast cancer was correlated with DNA repair proficiency and history of radiation exposure. The authors conclude that the findings suggest that there is a susceptibility factor (deficient repair of radiation-induced DNA damage during G2 phase, like in the cancer prone genetic syndromes) that may interact with exposures to low-levels of ionizing to increase the risk of developing breast cancer.

1.4. THERAPEUTIC EXPOSURE OF BREAST TISSUE TO LOW DOSE RADIATION

The best data available come from Sweden, from patients treated with ionizing radiation for benign breast disease, between 1924 and 1954. The results of the study have been published in 1993 and 1995 [12]. The cohort consists in 1216 women treated with radiation therapy (mean dose 5.8 Gy, range 0.003-50.14 Gy), and 1874 patients unexposed to irradiation, who had benign breast disease. Ages at the time of exposure between 8-74 (median 40 yr.). The total number of breast cancer observed was 278, of which 95 were in the unexposed cohort. In the analyses of the dose response relationship, for doses less than 5 Gy there was a clear dose-response linear relationship, with no threshold. This may support the working hypothesis of the mechanisms of carcinogenesis that is that it is a single cell origin [13].
At doses higher than 5 Gy there is an increase also, but with a leveling off in the increase of relative risk, because the cell killing became obvious. This also has been observed in the New York mastitis study for doses greater than 3 Gy, but in many other studies, this trend has not been found, but the information that these studies provide on high doses very limited.

1.5. SCATTERED IRRADIATION OF CONTRALATERAL BREAST TISSUE IN RADIOTHERAPY FOR BREAST CANCER

This issue has also been extensively studied. Boice reported data form the Connecticut tumor registry, on 41000 women in a typical case control study [5, 14]. The conclusion was that radiotherapy for breast cancer contributed little to the already high risk for contralateral breast cancer. In their experience less than 3 % of second breast cancer in the cohort can be attributed to pervious ionizing radiation treatment. The risk however is significant in women who underwent radiation at a relatively young age (< 45 yr.) (RR 1.59). Exposure after the age of 45 entitles a minimal risk of radiation induced breast cancer. Other authors [15,16] have found similar conclusions. In a attempt to reduce the scatter dose to the contralateral site, Macklis has developed a breast shield [17].

Results.

2. THERAPEUTIC DOSES OF RADIATION AND BREAST CANCER

Several studies of patients treated for Hodgkin's disease have shown an increased risk of second breast cancers [18,19]. Problems with these studies include small patient numbers, short follow-up time (less than 15 years), incomplete treatment information and an emphasis in hematological malignancies. Patients treated for Hodgkin's disease (as opposed to other malignancies) are at particular high risk of breast cancer because: a) Excellent prognosis for irradiated patients. b) Young age at exposure that increases the time at risk. c) Exposure at a physiologically vulnerable puberty period. d)-Large amount of breast tissue that receives primary or scatter radiation. Several large retrospective reviews of patients treated for Hodgkin's disease is now available and provides risk estimates for subsequent breast cancer and give suggested follow up guidelines.

One of the first reviews was published by Kaldor [20]. He reported the incidence of second malignancies following treatment of several types of cancer using 11 population-based registries including over 133,000 patients. No information was available on treatment given or other risk factors. Overall, the risk of second cancer at least 5 yr. after treatment for Hodgkin's disease was 90% greater than expected (415 vs. 218). Breast cancers were increased (62 observed vs. 44 expected. RR=1.4). The incidence peaked between 10-15 yr. of follow up.

The data from the British National Lymphoma Investigation on 2846 patients treated for Hodgkin's disease between 1970-1987 was reviewed by Swerdlow [21]. Mean follow up differed by treatment category causing XRT treated patients to have longer follow up. 113 second primaries were recorded for a RR=2.7. Most of these were hematological (only 6 breast primaries: RR=1.2). Patients treated with radiotherapy alone did not have a increased leukemia risk. Yahalom [22], form Memorial Sloan Kettering Cancer Center found similar findings and recommended mastectomy as the treatment of choice for these patients, and suggest screening mammography 8 years following radiation. Radiation induced breast cancers did not differ significantly, form the pathological point of view with a cohort of patients with breast cancers not induced by radiation.

Hancock from Stanford Reviewed records of 885 women treated for HD between 1961-1993 (with a mean follow up of 10 years) [23]. 25 patients developed breast cancer (RR 4.1)

> Age at time of radiation influenced risk. The biggest RR was for patients younger than 15 years (136), versus 19 for patients ages 15 – 24, 7 for those between 24 – 29, and 0.7 for those older than 30.
>
> Length of Follow up also turned out to be an important factor. If less than 15 years, R= 2.0, versus 13.6 for patients with more than 17 years of follow up.

Chemotherapy increased the risk of breast cancer22/26 cancers arose within or at the margin of the radiation field. Majority also arose in full dose area (4 Gy).

Leeuwen has reported several analysis on patients treated for Hodgkin's disease in the Netherlands [18,24], including a 20yr. follow up study of 1939 between 1966-1986. Overall, the RR for second cancer was 3.5. The overall risk of breast cancer was not increased (RR=1.1), but when analyzed by age at irradiation, those with 15 years of follow-up had a RR=4.1 if treated at age 20-29, compared with RR=41.8 for those treated at age less than 20.

Detailed dosimetrical analysis, including 3-D differential dose volume histogram have been developed [19,25,26] to determine doses to various parts of the breast in order to develop a linear model for carcinogenesis. This model attempts to take into account the bimodal dose distribution within the breast and come up with an integral dose to predict for secondary breast cancer.

Conclusions.

1. The RR for developing breast cancer after irradiation for Hodgkin's disease is somewhere between 4 and 40 depending on age of exposure and length of follow-up.
2. It is unknown whether the increased incidence represents true disease induction or is a mere shift in the age curve
3. Chemotherapy might have an additive role, although lack of chemo only treated patients makes this difficult to assess
4. Vigilant screening is necessary but probably not until 8-10 years following irradiation.
5. There is evidence for non-proliferative and proliferative disease induced by radiation of the breast parenchyma. The correlation is strongest for the group of ages 40-49 at the time of the exposure.
6. The excess of breast cancers appears to be confined mainly to the group of women exposed before 40 years of age.
7. The increased rates of breast cancer are not apparent until about 10-15 years after the initial exposure.
8. Breast cancer is not significantly increased with occupational exposure to ionizing radiation
9. For exposures to doses less than 5 Gy there is a clear dose-response linear relationship, with no threshold
10. At doses higher than 5 Gy there is an increase also, but with a leveling off in the increase of relative risk, because the cell killing is obvious

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Influence of dose per fraction on 7 days per week fractionation in radiotherapy

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Abstract

To evaluate the effect of the dose per fraction in a radiotherapy schedule of 7 fractions per week, and compare it with a conventional one of 5fr/w, 2Gy/fr, we use computer simulations methods taking into account the tumor proliferation. We have a significant increase of TCP with regard to te conventional schedule for 7 days per week programmes in which the dose per fraction is =1.7 Gy.

Introduction

In the radiotherapy of some tumors, like head and neck cancers, it is a fact that the overall treatment time has a great influence on the local control. Therefore, an increase in the prescribed treatment time produces a significant fall of the tumor control probability. The reason of this is to find in the malignant clonogens proliferation, which can be, in certain cases, very important in the final phase of the treatment, in which the doubling time reaches values of a few days [1,2]. Consequently, it is reasonable to conclude that a shortening of the duration of schedules can increase the effectiveness of the radiotherapy. This is the accelerated fractionation, which, in its pure version, consists in a shortening of the overall treatment time without reducing the fraction size or the total dose. This can be acomplished by delivering more than one daily fraction five days per week or one daily fraction six or seven days per week. However, the concept of accelerated fractionation has been extended to include other fractionated schedules like the continuous hyperfractionated accelerated radiotherapy (CHART), split-courses, concomitant boost and those in which the total dose delivered per week is progressively increased during the course of treatment [3].

The results of randomized clinical trials have been published for complex schedules [4,5], however, we do not have clinical results of more simple ones, like those in which the dose per week is progressively increased. Although the examinated schedules in references [4] and [5] show that the tumor clonogen proliferation is determinant in the therapy effectiveness, these schedules produce a high toxicity, what suggests the need of analyzing other ways of shortening the overall treatment time.

One of the most simple accelerated schedules which can be designed consists in a daily irradiation every day of the week. Using daily fraction of 2 Gy, the high incidence of severe acute reactions and consequential late effects suggests that this schedule gives an unacceptable toxicity [6]. Nevertheless, it is possible to shorten the treatment time decreasing the dose per fraction and maintaing the total dose and the seven days per week programme, for example, reducing from 2 to 1.8 Gy the dose per fraction, although results of this kind of schedule are not available yet [7].

The aim of this study is to evaluate the influence of dose per fraction in 7 days per week fractionated schedules. For that, we will use computer simulation methods based on Monte Carlo techniques.

Material and Methods

To obtain realist results we will use, there where necessary, the data for multicellular tumor spheroids of the MCF-7 breast cancer which our group has studied for the last years [8].

We make the computer simulation of a fractionated treatment similar to the actual situation in which, after surgery of the tumor, the malignant clonogens cluster in microscopical aggregates before the treatment. Two thousand virtual tumors which contain between 5000 and 50000 clonogens are produced according to a uniform distribution, this implies tumors diameters between 0.5 and 1 mm. This sort of distribution is the best one to reproduce the experimental data obtained for the sizes of the MCF-7 spheroids. This number of tumors guarantees a correct statistical behaviour. The growth is introduced by the exponential model for different values of doubling time (T_D). For each dose per fraction we calculate the mean surviving fraction (SF) by the linear-quadratic model. Possible differences in the response of the tumor clonogens to the radiation for each tumor of the sample have to be considered. These differences can be due to the distinct locations, components and hypoxia in a true situation. In order to take into account this fact, we assign a value of SF to each one of the sample tumors normally distributed around the mean value, and with a standard deviation that implies maximum differences of 10% in relation to the mean. The irradiation programme is simulated by considering that the cell proliferation and cell death are described by binomial statistics. The probability of tumor cure is determined by counting the proportion of tumors containing no surviving clonogens at the end of treatment. In order to make the final analysis of the control data which the simulation provides, and to compare the different fractionated schedules, we will use the logistic model which, although it does not have biological base, fits well the data.

Results

Following the described method, we have analyzed a *conventional* schedule, 2 Gy daily irradiation from Monday to Friday, and 7 fractions per week with a daily irradiation between 1-2 Gy.

In all the simulations the parameters values used for the linear-quadratic model are the ones obtained through clonogenic assay for monolayer culture of the MCF-7 cell line, $\alpha = 0.32\ Gy^{-1}$ and $\beta = 0.023\ Gy^{-2}$ [9].

The TCP results have been fitted by means of the logistic model. The smallest obtained value for the goodness of these fits is r^2=0.9996. In Figure 1 we can see some cases of the simulation results and their fits by the logistic model for a conventional and accelerated schedule, for T_D = 4 d and T_D = 15 d. The dose per fraction is 2 Gy in the four cases.

By using the fit results for given values of T_D an dose per fraction, we have calculated the TCP for an accelerated programme in which the total dose is the same to the one which produces a TCP = 0.5 according to a conventional schedule of 5 fraction per week of 2 Gy. Figure 2 shows the results of this calculation for several doubling time values and doses per fraction that are between 1 and 2 Gy. Here we represent the level of TCP = 0.5, in order that we can see immediately whether a given schedule of 7 fraction per week is more effective than the corresponding one to the same doubling time for conventional fractionation.

For doubling times between 4 to 30 days, and for the conditions in which the simulation has been carried out, we have a significant increase of TCP with regard to the conventional schedule for schedules of 7 days per week in which the dose per fraction is =1.7 Gy. For a dose per fraction of 1.7 Gy, the TCP increase in relation to TCP = 0.5 of the conventional programme is 2.94% for T_D = 15 d and 22.4% for T_D = 4 d; for a dose per fraction of 2 Gy the increase is 14.36% for T_D = 15 d and 53.48% for T_D = 4 d.

Discussion

In the simple case studied in this work, two factors contribute to the loss of tumor control when the dose per fraction is reduced: the first one is the increase of the overall treatment time and, as a result, it is related to the tumoral proliferation; the second one is a value of the β parameter in the linear-quadratic model greater than 0. This second factor produces that the TCP decreases in the 7 fractions per week, in relation to the conventional schedule, for a dose per fraction which in the first one gives rise to an overall treatment time equal to the second one. Thus, the total dose which produces a TCP = 0.5 for the conventional schedule is aprox. 40 Gy (we always suppose that the treatment starts on Mondays); to deliver this same dose in an identic time according to the 7 fractions per week schedule, we have to use a dose per fraction of 1.54 Gy which, if β is equal to 0, would also produce a TCP = 0.5, however, with the α and β values used in this work, the result for TCP is 0.46 (see Figure 2). In conclusion, a β parameter value greater than 0 produces a decrease of the effectiveness of the shortening in the overall treatment time in an accelerated schedule in which the dose per fraction is smaller than 2 Gy.

We wonder whether a model like the Poisson model is able to reproduce these results or, more generally, whether we have the need of employing simulation methods in order to estimate the effect of a therapeutic programme. In the case mentioned above, where TCP is 0.34, the predicted value by the Poisson model is 0.30. This result is not surprising because the Poisson model underestimates the cure capacity when proliferation occurs (see Tucker *et al.*[10]). As we see, the TCP variation is of 13%, but this is not the only limitation of Poisson model. The simulation methods, based on Monte Carlo thechniques, let us reproduce true situations where a great statistical variability of the more outstanding parameters is frequent, what cannot be done by means of simple analytical models.

In summary, it is possible to obtain a therapeutical gain using accelerated schedules of 7 fractions per week with dose per fraction under 2 Gy, this can produce a reduction of the complications. Thus, making randomized clinical trials can be considered in order to compare these schedules to the conventional ones. On the other hand, and if we take into account the accelerated repopulation in some tumors like head and neck cancers, it is possible that the use of 7 fractions per week schedule only for the last weeks of treatment increases the tumor control rate. At the moment we are studying this with similar methods to the ones used in this preliminary work.

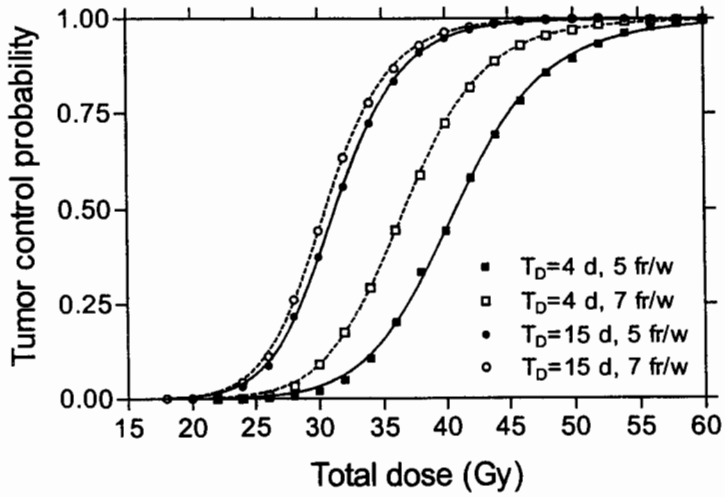

Figure 1: Comparison of TCP's obtained in seven and five fractions per week schedules for T_D equal to 4 and 15 days, such as indicated in the graph. The curves fits the data according to logistic model.

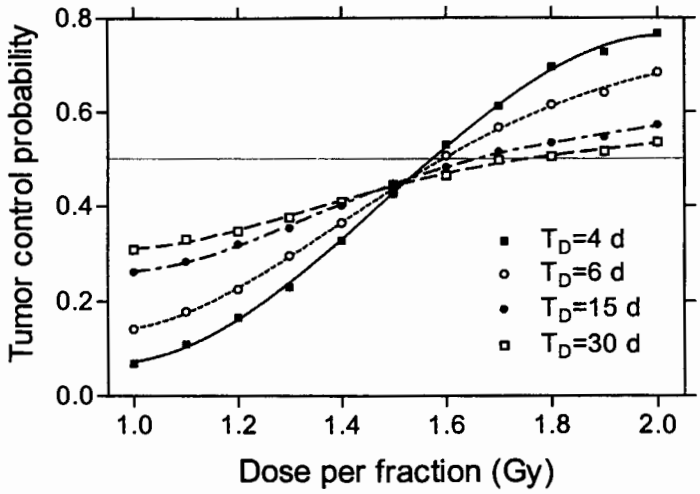

Figure 2: For a given value of T_D, each point represents the TCP of an accelerated programme with a given dose per fraction if it is reached the same total dose which produces TCP = 0.5 for a conventional schedule, 5fr/w 2Gy/fr. The curves are obtained fitting a polynomial funtion of degree 4. Uncertainties correspond to one standard deviation and are smaller than the symbols which represent points.

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Protección Radiológica en Cribado Mamográfico. Justificación de la Práctica.

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Abstract
In this work we expound briefly some of the aspects which must be taken into account for the justification of breast screening programmes according to the ICRP. It's no possible to quantify such aspect like the radiation non associated detriment, that involves psicological and behavioral implications of abnormal mammograms. But generally, for women between 50 and 65 years the relation detected cancers/induced cancers is 1000, the existence of women groups in which dose may be so high make the implementation of a quality assurance program unavoidable, in which quality control is only a part. Screening used resources could be destinated to anothers aims and so, the true ethical dimmension of this problem that it doesn't exist a deep discussion about, is arised. In Spain, for example, screening programms reports don't take account questions associated to the economical cost.

Introducción

Un programa de detección precoz del cáncer de mama mediante cribado mamográfico produce un aumento de la exposición global a la radiación, por lo tanto se trata de una *práctica* según el *sistema de protección radiológica* de la Comisión Internacional de Protección Radiológica (ICRP). En este ensayo examinaremos el principio de *justificación* aplicado a dicha práctica, consistente en que, antes de emprenderla, ha de garantizarse que produce un beneficio neto para los individuos expuestos a la radiación o para la sociedad [1]. Calculamos el beneficio, B, mediante la siguiente ecuación:

$$B=V-(P+X+Y), \qquad (1)$$

donde V es el valor bruto de la actividad, que incluye el valor del producto resultante y los beneficios de cualquier índole; P incluye los costes de producción de cualquier clase, como los sociales, algún tipo de perjuicio no radiológico y los costes de protección contra riesgos no radiológicos; X es el coste de la protección radiológica e Y el coste del perjuicio producido por la radiación.

Si $B>0$ la práctica está justificada. La justificación de una práctica radiológica sólo difiere de la justificación de cualquier otra actividad humana en que, de forma explícita, se incluye en la expresión (1) (o alguna semejante) un término asociado al riesgo radiológico. Por tanto, la justificación de la puesta en marcha de un programa de detección precoz del cáncer de mama mediante cribado mamográfico, se extiende mucho más allá del ámbito de la protección radiológica. Nos encontramos así en el umbral de un delicado paseo en el que sólo aspiramos a indicar algunos de los aspectos que deben considerarse en el proceso de justificación.

Los beneficios

El cáncer de mama es el tumor más frecuente en mujeres y la primera causa de muerte por cáncer entre ellas, en la provincia de Granada tuvo una incidencia anual media de 46,6 por 100.000 habitantes en el período 1988-90 [2,3]. Por consiguiente, esta enfermedad puede considerarse un problema sanitario importante que, desgraciadamente, no admite una prevención primaria eficaz, con lo que se da la primera exigencia para plantear un programa de cribado [4]. Es comúnmente aceptado que la mamografía permite, mejor que cualquier otro medio, detectar precozmente el cáncer de mama. La tasa de detección usual en los programas de cribado es de unos pocos casos por mil; así, en la primera vuelta del *Programa de Prevención del Cáncer de Mama en Cantabria* se detectaron 4,3 cánceres por cada mil mujeres (103 en un total de 23.945 exploraciones) [5], siendo este valor de 4,08 por mil en Galicia [6]. Estos resultados son similares a los que presentan otros programas extranjeros, como el inglés, que produce una tasa de detección del 3,8 por mil [7]. Ahora bien, no tenemos un certeza absoluta de que la detección precoz permita cambiar la *historia natural* de la enfermedad, lo que no debe confundirse con el hecho de que el pronóstico de un cáncer precozmente detectado sea mejor; un cáncer puede detectarse tempranamente y la supervivencia que produce el tratamiento puede ser más larga, sin embargo, la pregunta es si la muerte se adelanta o se

retrasa con respecto al momento en que se hubiese producido al detectarse la enfermedad por sus síntomas clínicos. Si la muerte ocurre en el mismo momento para ambos casos, entonces el cribado sólo aumenta el tiempo durante el cual la paciente sabe que tiene cáncer. Por tanto, es mejor indicador del beneficio del programa de cribado la tasa de mortalidad que la tasa de detección.

En 1971, el estudio del *Health Insurance Plan* [8] mostró que el cribado reduce la mortalidad de las mujeres que tienen entre 50 y 64 años, pero no la de aquéllas entre 40 y 49. Hoy el debate está mucho más activo que nunca tras la finalización de varios estudios aleatorios controlados, varios de casos control, algunos meta-análisis y la publicación de cientos de editoriales y artículos de opinión; lo que ha llevado a una "Conferencia de Consenso" como la *National Institutes of Health Consensus Development Conference* (1997) [9]. El planteamiento más aceptado es que la mortalidad se reduce claramente para mujeres de entre 50 y 65 años, por lo que la "Conferencia de Consenso" recomienda el cribado anual para ellas, pero no para las mujeres con edades entre los 40 y los 49 años, que decidirán, junto con su médico, la conveniencia de someterse a una exploración mamográfica teniendo en cuenta sus factores de riesgo particulares. En España, la mayor parte de los programas de cribado mamográfico se dirigen a las mujeres de entre 50 y 65 años, siguiendo las directrices europeas que recomiendan el cribado a mujeres de más de 49 años aunque no limitan la edad máxima [10], con una frecuencia de mamografía entre 2 y 3 años y dos proyecciones en todas las mujeres que entran por primera vez en el programa; para esta población se ha estimado una reducción de la mortalidad a los 7-10 años entre el 20% y el 30%. Estos valores son citados para justificar un programa de cribado [11,12], sin embargo, no faltan datos recientes que los contradigan, como es el caso de un análisis, no exento de polémica, de la experiencia sueca desde 1987 a 1996. Dicho estudio no muestra una reducción significativa de la mortalidad por cáncer de mama en mujeres de entre 50 y 78 años, ya que ésta permanece constante a lo largo del período citado, aunque la participación en el programa es muy alta, del 80%, lo que se considera óptimo [13,14]. Admitiremos pues que parece existir un aumento de la supervivencia entre las mujeres que siguen los programas.

Entre los beneficios no relacionados con la mortalidad de un programa de cribado mamográfico, se considera que la detección precoz de la enfermedad permite una terapia menos intensa. Esta afirmación puede discutirse, ya que no existe un acuerdo amplio sobre que la detección precoz modifique *per se*, por ejemplo, la proporción de mastectomías [15].

Costes no asociados a los efectos de la radiación

Nos ocupamos ahora de los términos P y X de la ecuación (1), en los cuales se incluyen todos los costes excepto los relacionados con los efectos de la radiación. Estarán ahí, por tanto, el valor de las instalaciones, del equipamiento, del personal, del mantenimiento técnico, del programa de calidad y otros. Quizá nos parezca que estos gastos pueden cuantificarse con relativa sencillez, sin embargo, en las memorias de los programas de detección precoz se nos ofrecen los datos estadísticos asociados al diagnóstico y posterior seguimientos de las mujeres que participan en ellos, pero no datos económicos sobre estas cuestiones más pecuniarias pero de innegable importancia (al menos para una ecuación como la (1) donde todos los términos tienen igual peso simbólico, siendo el valor conjunto de P y X muy grande).

Tratamos seguidamente de algunos aspectos de más difícil cuantificación, pero que están incluidos en el apartado de costes no radiológicos.

Algunos estudios muestran que las mujeres que son citadas nuevamente por mamografías sospechosas pueden padecer angustia psicológica [16]. No es una sorpresa que las mujeres que vuelven a ser llamadas porque su mamografía es anormal padezcan ansiedad mientras esperan los nuevos resultados; sin embargo, el incremento de ansiedad en este grupo no es trivial y puede continuar algún tiempo después de que las mujeres sepan que sus resultados son normales. Para entender la importancia de esto, basta un ejemplo: en Cantabria el 12,98% de las mujeres incluidas en la primera vuelta *del Programa de Prevención del Cáncer de Mama* fueron llamadas de nuevo para exámenes ulteriores (un total de 3.108 mujeres) [5]. Por consiguiente, los programas de cribado no están exentos de costes psicológicos para las participantes. Esto es particularmente cierto si se incluyen mujeres más

jóvenes (40-49 años), ya que aumenta el número de falsos positivos [16]. Por último, las campañas de cribado influyen sobre la percepción que tienen las mujeres del cáncer de mama, transmitiéndoles la idea de que se trata de una enfermedad muy común que admite curación si se detecta precozmente y, por tanto, que el cribado es efectivo para alargar la vida, de manera que se sobrestima la capacidad de la mamografía para reducir el riesgo. Esta no es, de ningún modo, una cuestión de poca monta; destaquemos que existe una conciencia colectiva de que *el cáncer detectado con prontitud se cura*, lo que está muy lejos de ser una "evidencia" científica.

El coste por riesgos radiológicos

La magnitud que permite expresar, en el caso de la radiación, la combinación de la probabilidad de que se produzca un efecto para la salud y la gravedad de dicho efecto es el *detrimento* [1]. Efectuaremos una estimación sencilla del detrimento asociado a las exploraciones mamográficas de un programa de cribado usando la siguiente expresión:

$$Y = n \cdot D \cdot r_l \qquad (2)$$

donde n es el número de años que las mujeres participan el el programa de cribado, D la dosis para cada año de participación (que por simplicidad suponemos constante durante todos los años que las mujeres siguen el programa) y r_l es el coeficiente de riesgo de cáncer de mama letal. La ecuación (2) no incluye el riesgo de efectos hereditarios, puesto que la zona irradiada y la edad de las mujeres que participan en el programa de cribado hacen que éste sea prácticamente nulo. Tampoco incluye la componente del detrimento asociada a la pérdida de vida y a los cánceres no mortales, ya que su contribución no es muy grande, en especial para las edades consideradas, haciendo, por otra parte, más complicado el cálculo.

Para sustituir los símbolos de la ecuación (2) por números, empezamos suponiendo que las mujeres siguen un programa de detección precoz del cáncer de mama en el que se realizan 2 proyecciones cada dos años desde los 50 a los 64, así tenemos n=7. Las recomendaciones internacionales para la dosis por proyección en el cribado nos hablan de 1 mGy (OIEA, 1994), lo que supone una *dosis equivalente* de 1 mSv ya que ésta se produce por radiación X. Pero más que a las recomendaciones nos atendremos a los valores medidos en la práctica: un estudio realizado en el área de Madrid [17] nos indica valores medios de 1,5 y 1,7 mGy por placa, con y sin rejilla respectivamente, para una mama comprimida de 5 cm de espesor, y los resultados son semejantes a los obtenidos en otros estudios europeos [18]. Por tanto, usaremos un valor de 1,6 mSv para la dosis en nuestros cálculos con la expresión (2).

El coeficiente de probabilidad de cáncer mortal en mama para mujeres de entre 20 y 64 años (véase la tabla B-13 de la referencia [1] y téngase en cuenta que el valor allí indicado es un promedio para ambos sexos) se estima igual a $4{,}4 \cdot 10^{-4}$ mSv^{-1}, es decir, por cada 10.000 mujeres irradiadas con 1 Sv, entre 4 y 5 padecerán un cáncer de mama.

Ya estamos en disposición de resolver (2):

$$Y = 7 \cdot 4 \cdot 1{,}6 \cdot 10^{-3}\,\text{mSv} \cdot 4{,}4 \cdot 10^{-4}\,\text{mSv}^{-1} = 1{,}9 \cdot 10^{-5} \qquad (3)$$

De cada 100.000 mujeres que completan el programa de los 50 a los 64 años, 2 sufren un cáncer de mama como consecuencia de la radiación.

No hemos considerado en nuestros cálculos el número de placas rechazadas ni otras cuestiones prácticas de indudable importancia, pero el valor obtenido nos servirá de referencia. Por otra parte, estos cálculos se basan en una estimación colectiva de las dosis y no distinguen los casos particulares, en especial la existencia de subgrupos de mujeres que por sus características anatómicas precisan de una mayor dosis para obtener estudios mamográficos válidos.

El beneficio neto

Ya tenemos los ingredientes con que resolver la ecuación (1). Para ello necesitamos cambiar los símbolos genéricos de esta expresión por números, pero no tenemos datos del coste económico de los términos P y X; no sabemos cuantificar el detrimento que no está asociado a la radiación, como la angustia psicológica, empeoramiento de la calidad de vida, y otros; no hay lugar en este trabajo para una discusión sobre la cuantificación en términos monetarios de la vida humana... Según se indicó antes, las tasas de detección para la primera ronda de un programa de cribado están entre 4 y 5 cánceres por 1.000 mujeres, reduciéndose esta cifra hasta 2 ó 3 casos de cada 1.000 en las siguientes. Frente a esto, el número de cánceres inducidos es de 2 en

100.000 mujeres, con lo que el cociente entre el cáncer detectado y el cáncer inducido está en torno a 1.000. Nuestro tosco procedimiento de cálculo arroja valores semejantes a los de trabajos más rigurosos [19]. Este halagüeño resultado no debe ocultarnos algo sobre lo que ya dimos una pista en el apartado anterior. Las estimaciones numéricas se han realizado con parámetros medios del conjunto de las mujeres incluidas en el programa de cribado. No hemos tenido en cuenta que existen mujeres para las cuales la capacidad de detección es menor por sus características anatómicas, como la mayor densidad del tejido mamario; y mujeres para las que las dosis pueden ser muy elevadas por uno o varios de estos tres motivos: repetición de placas, necesidad de realizar varias placas en una misma proyección si la mama comprimida tiene un área muy grande y espesor mayor que el medio (5 cm en nuestro caso). Por otro lado es posible que, para una misma mujer, tengamos mayor dificultad en detectar un cáncer y que, además, precisemos mayor dosis para obtener imágenes válidas. En estos casos el balance coste-beneficio es muy desfavorable: véase Law 1997 [20], donde se presenta la proporción de mujeres incluidas en el programa de cribado del Reino Unido para las cuales la probabilidad de inducción de cáncer supera a la de detección.

Conclusiones

La cuestión sobre si el cribado mamográfico está justificado se encuentra abierta. Si deseamos tener datos objetivos con los que discutir sobre este tema es necesario establecer, junto con cada programa de detección precoz, un sistema de calidad mediante el cual se aporten los indicadores adecuados para evaluar todos los aspectos que se relacionan con el beneficio y los costes de dicho programa; en caso contrario será imposible poseer datos tan básicos como las dosis a las que las mujeres se ven expuestas.

Es innegable que existe una "opinión ambiental" favorable a los programas de detección precoz, pero no es menos cierto que este tipo de creencias coartan las reflexiones maduras en torno a los problemas sobre los que se ciernen. Los recursos invertidos en el cribado podrían emplearse en otros usos sanitarios y esto plantea la verdadera dimensión ética del problema que está, más que en la cuantificación del dinero adjudicado a una práctica, en la conveniencia de dedicar ese dinero a otros fines más efectivos desde el punto de vista sanitario.

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FORM B
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PATIENT EXPOSURES FROM DIAGNOSTIC RADIOLOGICAL PROCEDURES IN INDIA

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ABSTRACT

It is very well recognised that the ratio of diagnostic information / patient dose must be optimised in diagnostic radiology for each type of examination. Regulatory authorities in various countries are now engaged in developing dose constraint values for various X-ray examinations. In a co-ordinated research project, Atomic Energy Regulatory Board (AERB) and Bhabha Atomic Research Centre (BARC), India, conducted a nationwide survey to assess the impact of diagnostic radiological practices on population dose in the country. Forms were designed to collect data on :-(i) X-ray examinations, (ii) details of X-ray machines, (iii) type of work and workload in different hospitals, and (iv) X-ray examination techniques and associated technical parameters. Entrance skin doses were estimated by using specially designed and calibrated TLD postal packs. The entrance skin dose was estimated for a particular examination in a hospital on the basis of TL reading of disc under perspex filter, taking into account the focus-to-skin distance, back-scatter factor, the mass energy absorption coefficient and the mAs actually used for the examination. The analysis of entrance skin doses estimated for 12 common X-ray procedures in these 40 hospitals showed that for the most part these doses fall within the reference levels specified in the Basic Safety Standards (BSS).

1. Introduction

In diagnostic radiology, it is prudent to optimise the ratio of diagnostic information/ patient dose for each type of examination. Since the radiation safety standards are not optimised in all the hospitals, there is a wide variation in this ratio. Many countries have introduced comprehensive Quality Assurance programmes for diagnostic procedures, which has led to the gradual reduction in the patient doses, over the years, for the same acceptable quality of the diagnostic images. The dose reductions have now been optimised at levels, which can be, considered minimum for the diagnostic information expected with good quality images. For optimising protection for medical exposures these reference doses should be followed as guidance levels for different procedures. Since the medical procedures are justified because they directly benefit the patients, less attention has been given to the optimisation of protection for medical exposures than for most other applications of radiation sources. As a result, there is considerable scope for dose reduction in diagnostic radiology (ICRP-60). Regulatory authorities in various countries are now engaged in developing dose constraint values for various X-ray examinations.

In a co-ordinated research project, Atomic Energy Regulatory Board (AERB) and Bhabha Atomic Research Centre (BARC), India conducted a nationwide survey to assess the impact of diagnostic radiological practices on population dose in the country. For this purpose, support of Radiological Safety Officers (RSOs), attached to different Radiotherapy centres, in 10 different

regions of the country was sought. These RSOs were designated as chief investigators for collection of the data. Forms were designed and were utilised to collect data on :-(i) X-ray examinations including age and sex of patients and projection, (ii) Details of X-ray machines, e.g., Type, make & model, kVp (max), mA (max), total filtration, beam collimation method, lead equivalence of the Pb glass backing of fluoroscopic screen, focus-to-table top distance, availability of radiation safety accessories, etc., (iii) type of work and workload in different hospitals, and (iv) X-ray examination techniques and associated technical parameters. The data collected from various hospitals were used to estimate the frequency of X-ray examinations as well as the age and sex wise distribution of the patients in the country. The data also helped in assessing radiation safety status of radiology departments and in finding inadequacies in radiation protection features of X-ray units in the country. This data was collated and analysed at BARC. As a part of the project, entrance skin doses for most common X-ray examinations were measured in 40 different hospitals using TLD postal pack developed in the Division[1]. Entrance skin doses were estimated by using TLD postal packs in different hospitals distributed in different regions of the country. RSOs at the participating centres assisted in irradiation of TLD postal packs used for estimation of entrance skin doses during different diagnostic radiological procedures in different hospitals.

2. TLD postal pack

The TLD postal pack consists of $CaSO_4$: Dy teflon TLD discs (0.8 mm x 7 mm ϕ), arranged in 4 rows with 4 TLD discs in each row, covering each row of TLD discs with 4 different filters on front side viz. 0.5 mm perspex, 0.3 mm Cu, 0.5 mm Sn + 0.3 mm Cu and 1.0 mm Cu and a 2.0 mm copper backing plate. The size of the pack is only 6 cm x 6 cm x 0.4 cm. $CaSO_4$: Dy Teflon TLD discs were used because of high sensitivity of $CaSO_4$: Dy phosphor and its nearly flat energy response (within $\pm$ 10%) in diagnostic X-ray range of 40 kVp - 125 kVp. The TLD postal pack facilitates simultaneous measurement of output, tube potential (kVp), HVT and total filtration. The output of the X-ray tube is measured by TL readouts of discs under 0.5-mm thick perspex filter. The HVT is estimated by using the ratio of TL readouts under 1 mm thick copper filter to that under 0.5 mm perspex. For the estimation of tube potential $\geq$ 75 kVp, the ratio of TL readouts under combined 0.5 mm tin + 0.3 mm copper filter to that under 0.3 mm copper filter is used and for tube potentials < 75 kVp, the ratio of TL readouts under 1 mm thick copper filter to that under 0.3 mm copper filter is used. The ratio under 1 mm of copper to that under 0.3 mm copper increases linearly with tube potential up to 80 kVp, beyond which it becomes sub-linear, whereas the ratio under combined 0.5 mm tin + 0.3 mm copper to that under 0.3 mm copper increases linearly up to 125 kVp. For estimation of kVp and HVT from the ratios of TL outputs under various filters, as mentioned above, the ratios given in **Table-I** are used.

Table-I: Ratio of TL outputs under various filters for different Tube Potentials (kVp) and Half Value Thicknesses (HVT in mm Al) for TLD Postal Pack.

Tube Potential (kVp)	HVT (mm Al)	Ratio of TL Outputs		
		1Cu / 0.3 Cu	(0.5 Sn +0.3 Cu) / 0.3 Cu	1 Cu / 0.5 Perspex
60	2.325	0.1161	0.02684	0.01738
70	2.600	0.1743	0.02714	0.03267
81	3.040	0.2202	0.04501	0.04781
90	3.400	0.2497	0.06123	0.06413
102	3.950	0.3011	0.08622	0.08030
117	4.375	0.3114	0.10410	0.09194
125	4.956	0.3532	0.12013	0.11041

The TLD postal pack was found to measure tube potential with an accuracy of ± 5 kVp, in the range of 40 kVp to 130 kVp; the air-kerma output was within ± 5%; and total filtration was within ± 0.5 mm Al equivalence, for X-ray beams with a filtration above 2 mm Al equivalent.

3. Estimation of entrance skin dose

For estimation of entrance skin doses of patients undergoing various radiological examinations following procedure is adopted: - Irradiation of TLD postal packs (without patient) were made at focus-to-TLD pack distance of 500 mm. A range of kVp most commonly used in the hospital was used for irradiation. The mAs used corresponded to the kVp. **(Table-II)** Appropriate calibrations of TLD packs had been first made. The entrance skin dose was then estimated for a particular examination in a hospital on the basis of TL reading of disc under perspex filter, taking into account the focus-to-skin distance, backscatter factor, the mass energy absorption coefficient and the mAs actually used for the examination. Thus,

$$ESD_E = (\text{Air Kerma / mAs})_{50,\ kVp(E)} \cdot (50/\ FSD_E)^2 \cdot (mAs)_E \cdot (BSF)_{HVT\ (E)} \cdot (\mu_{en}/\rho)^{muscle}_{air}$$

Where,
ESD_E is Entrance skin dose for examination (E),
$(\text{Air Kerma / mAs})_{50,\ kVp\ (E)}$ is the measured Output of X-ray tube per mAs on the central axis of the beam at 50 cm from focus, and tube potential kVp, used for the examination, obtained from TLD postal pack,
$(50/\ FSD_E)^2$ is inverse law correction for the focus-to-skin distance (cm) actually used for the examination (E),
$(mAs)_E$: mAs used for the examination (E),
$(BSF)_{HVT\ (E)}$: Backscatter factor for quality of beam used for the examination (E),
$(\mu_{en}/\rho)^{muscle}_{air}$: Ratio of mass energy absorption coefficient for energy used for the examination.

Table-II: Exposure Chart for TLD Postal pack
(For 20 x 20 cm^2 field at focus-to-pack distance: 50 cm)

X-ray Tube Potential (kVp)	Exposure (mAs)
40	1000
50	250
60	180
70	120
80	100
90	80
100	60
120	40

On the basis of number of X-ray examinations per 1000 population estimated during a previous survey,[2] and increase in the consumption of X-ray films and the population since then, the number of X-ray examination per 1000 population has been estimated as 150. The number of examinations has been estimated as 140 million per year. Age, sex and examination wise distribution of patients was obtained from the data collected in this survey. The data on details of X-ray equipment provided the status of radiation safety in diagnostic radiology. **Table-III** reports on analysis of the entrance skin doses during some common X-ray examinations. The mean, standard deviation, median, the first and third quartiles are shown in **Table-III.**

Table – III: An analysis of skin entrance doses during different examinations, as measured in 40 hospitals during the Co-ordinated research project on patient organ dose measurements during diagnostic radiology

Examination	Skin Entrance Dose (mSv)						
	Mean	SD	Median	First Quartile	Third Quartile	BSS guidance level	No. of values below BSS guidance level
Chest (PA)	0.23	0.10	0.21	0.16	0.29	0.4	37
LS (AP)	7.34	3.41	7.5	4.4	9.4	10	31
LS (LAT)	19.85	8.98	19.2	14.5	22.8	30	34
Pelvis/Hip(AP)	8.31	2.61	7.9	6.7	9.4	10	31
Abdomen (AP)	6.56	2.44	6.2	4.9	7.6	10	36
Skull (AP)	4.56	2.33	4.0	3.0	5.5	5	26
Skull (LAT)	4.37	1.53	4.2	3.1	5.2	3	8
CS(AP/LAT)	1.37	0.74	1.3	0.7	1.8	-	-
Urography	5.81	2.57	5.5	3.7	7.1	10	37
Extremities	0.35	0.25	0.29	0.19	0.39	-	-
TS (AP)	5.14	2.32	4.6	3.2	6.1	7	32
TS (LAT)	12.59	6.34	11.4	5.9	17	20	35

4. Results and Discussions

The BSS guidance levels and the number of values below the guidance levels, in the investigated diagnostic examinations, in the 40 Indian hospitals in the present survey, are listed in **Table-III**. It is obvious from this Table that there is a large variation in entrance skin doses for any particular examination from machine to machine, which is a common observation, in other countries as well. The analysis of entrance skin doses estimated for 12 common X-ray procedures in these 40 hospitals shows that, for the most part, these doses fall within the reference levels specified in the Basic Safety Standards (BSS). Guidance levels for different diagnostic X-ray examinations can be prepared following the method outlined above and these data can be used to obtain diagnostic information commensurate with clinical requirements without undue radiation doses to the patient.

5. References

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Methodology for Comprehensive Patient, Worker and Public Radiation Protection Considerations While Introducing New Medical Procedures

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1. Abstract

Patient protection is a major consideration while introducing new medical procedure. But protection of the workers and the public should be considered too. A methodology of combining non-patient radiation protection considerations, with the introduction of new medical procedures is described. The new medical procedure was the Intracoronary Gamma Irradiation for the Prevention of Restenosis, by using Iridium 192 gamma radiation sources. The usual authors responsibility is the licensing of the use of radioactive materials while keeping public protection. According to this responsibility, the methodology's original orientation is public protection. As a result of coordination between several competent authorities, managed by the authors, the methodology was adopted for patient and worker protection too. Applicants, actually possible users (hospitals) of the new procedure, were obliged to plan medical procedures and working area according to dose limits and constrains as recommended by the International Atomic Energy Agency and local competent authorities. Exposure calculations had to consider the usual parameters as sources types and activity, dose rate and dose levels, duration and number of treatments. Special attention was given to the presence workers and public by chance presence in or near treatment area. A usual condition to give a license was the installation of continues (during treatment) radiation monitoring systems. But a special attention was given to physical barriers and procedures in order to stop unauthorized personal to arrive near to working area. Satisfactory stuff training for normal operation and emergency situations are essential, including appropriate safety procedures and the presence of safety assistance team while executing treatment

2. Notification and Justification

Catheter based intracoronary radiation plus stenting, or after stenting, is quit a new medical procedure[1]. There was a search for means to control restenosis following balloon angioplasty, and Intracoronary Gamma Irradiation is one of the promising of the anti-restenosis strategies[2]. Two types of radiation are used - gamma and beta. In this paper we will discuss only the use of gamma radiation.

One of the first obligations of any potential user of radiation sources is the notification of the competent authority[3]. This was done when a local representative of a producer of gamma-radiation anti-restenosis system, notified us about the wish to introduce the procedure to our country.

First radiation protection requirement is the justification of the practice. In our country different competent authorities has different responsibilities. The duty of justifying medical procedures is Ministry of Health's. A meeting of all parties concerned - Ministry of Health, Ministry of Labor, hospitals representatives was organized under the supervision of The Ministry of The Environment, Radiation Safety Division. All aspects of the new procedures were explained in detail. Applicants had to persuade that the new procedure produce

sufficient benefit to the patients and the society to offset the radiation harm that it might cause[3]. Some period later Ministry of Health gave the approval, namely - the justification.

3. Limits, Constrains and Optimization

Next radiation protection requirement is the optimization of protection and safety. The applicant have to make this optimization, based on guidance provided to him by the competent authority. In this case, the competent authority is Radiation Safety Division of The Ministry of The Environment. Based on BSS-115 standards, our country adopted the maximum dose limit for exposure of individuals of the public of 1 mSv/y[3]. The maximum dose constrain value that is allowed in association with any particular practice is 0.3. For this special and important practice we allowed the maximum constrain value. The meaning is that any applicant had to prove us that maximum public yearly exposure should not exceed 0.3mSv as a result of using this procedure. Attachment 1[4] describes the methodology we use to evaluate any application. All four hospitals that asked for such a license, fulfilled this demand. Actually only two hospitals are using this procedure, and dose levels measured in public areas were found smaller then predicted. Since actual procedures rate is less then planned, accumulated public exposure is much smaller then the maximum allowed by the constrain. Measured changes of workers accumulated doses were found negligible.

4. Other Requirements, Safety and Security, Intervention

The additional topics of radiation safety are elaborated in the BSS[3]. In order to guide applicants to prepare their requests and actual radiation protection means according to the methodology described in attachment 1, we provide them a general guiding questionnaire[4], based on the BSS and that is valid for all kinds of practices (Attachment.2). This questionnaire is built in a methodological way that leads the applicant step by step through all aspects of radiation protection and license request. It combines professional and administrative demands. Applicants should refer only to relevant topics.

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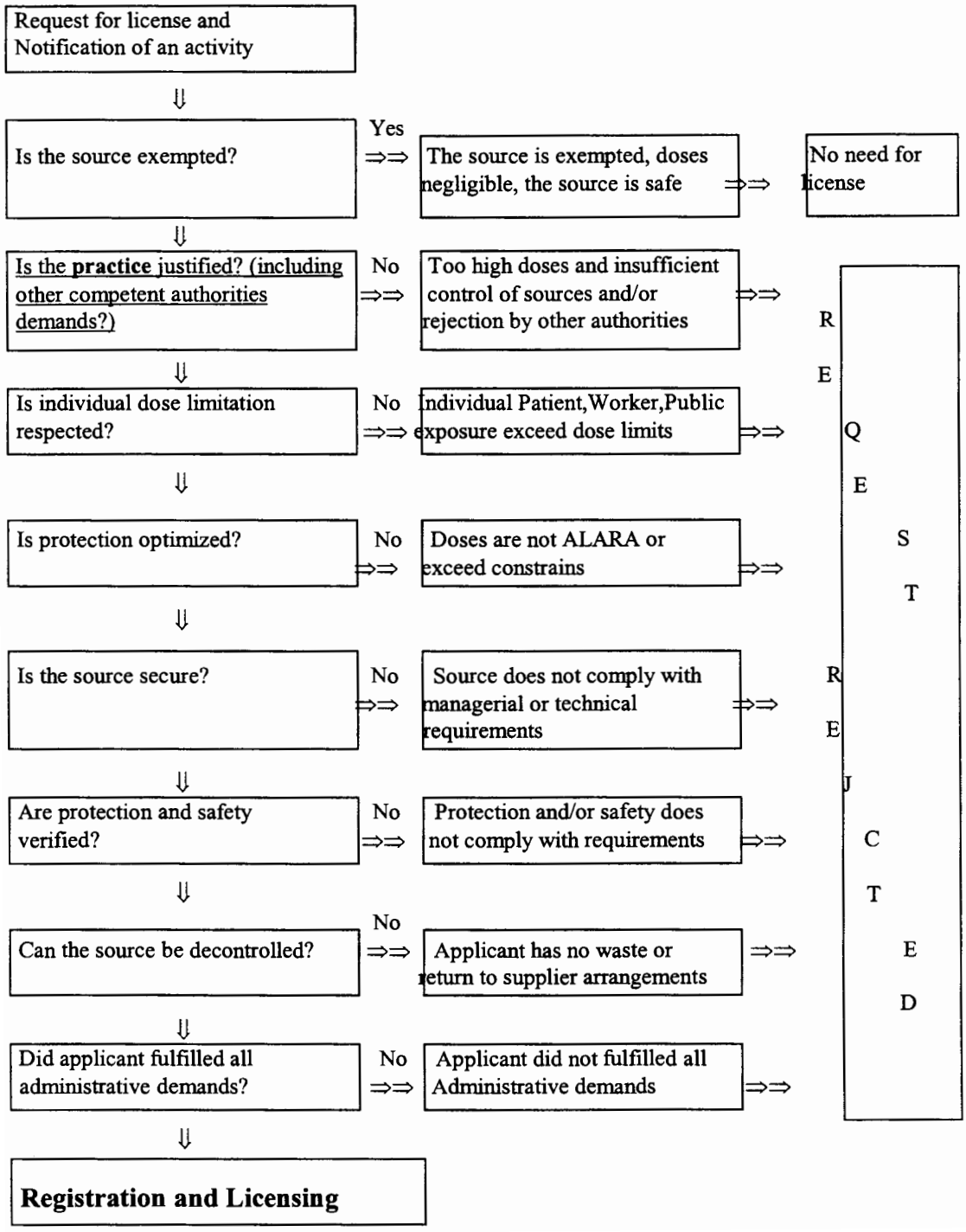
Attachment 1: Processing a license request



Attachment 2: a guiding questionnaire

1. Site Selection - safety and environmental impact assessment, regional mapping;
2. Practice in operation;
3. Reasons for the Practice, Justification;
4. Applicant's Safety and Radiation Protection Organization;
5. Names, position, qualification, responsibility, (curricula vitae for RSO and Operator);
6. Description of the work
7. Project, map, drawing, layout, (adequate drawing and scale) ;
8. Quantification of the radionuclides, types and uses, chemical and physical form;
9. Description of any apparatus containing sealed sources, with copies of any prototype test certificate supplied by the manufacturer demonstrating they met the ISO or equivalent standard, all sealed sources needs the test certification demonstrating that they meet with ISO or equivalent standards, including leakage test, also copy of catalogue or manual containing instruction or procedures for radiation protection and maintenance should be sent;
10. Description of the available instruments, portable and fixed monitor, for measuring dose rates and contamination levels, and its main characteristics, such integrated with access door interlocks, visible and alarm signs;
11. Description of storage facilities, for the radionuclides and the radioactive waste, warning and monitor system and access control, (adequate drawing and scale);
12. Description of the proposed waste management system, including disposal;
13. A formal method of assessment should be used for Safety Analysis for all Fixed Installation. It should be necessary to considered in detail each safety component, and types of failure and repercussion. Points of interest are connected to the viewing system, control room, points of access to exposed room, warning system, safety systems and interlocks, beam stops, radiation level detectors, fire control, ventilation system, including the quality assurance program, materials, shielding thickness, protective barriers, occupancy factors, and calculus, methods and results, as well as reference used by the applicant. The safety assessment should also give confidence that the proposed facility is capable, basically, of meeting the regulatory requirements for the management of waste
Defense in depth are requested for medical radiation beam therapy, accelerators, neutrons generators, industrial and research irradiation facilities and all manufacturing installation, including complex wet operations with risk of spills, labeled compound, and dry and dust operations or others as required by the competent authority;
15. Special design and procedures are requested for uses of unsealed radioactive sources including waste disposal system, decontamination, warning system and access controls;
Manual for Radiation Protection, including an effective occupational and public radiation exposure control; internal dosimetry evaluation; environmental contamination; classification of working places; protective measurements should be elaborated for appreciation and approval by the Competent authority, including optimization or alternatives;
17. Program for training including Initial, On-the-job and refreshment;
18. Administrative Control, records, workers health, source accountability, calibration of survey instruments, calibration and maintenance of devices, leak test program, old sources in use, spent source;
19. Movement of Sources, internal and external of the installation;
20. Physical Security;
21. Emergency Response;
22. Special operational procedures for external uses of radionuclides, sealed or unsealed sources;
23. Consultant Evaluation on Radiation Protection Quality Assurance (In case of any external Consultant on Safety and Radiation Protection)

RADIATION PROTECTION OF PATIENT IN NUCLEAR MEDICINE

Rustem **Paci** Institute of Public Health,_

According to the recommendations of the ICRP the basic rules of any application of radiation in medicine are:

Justification:
The net benefit to the exposed individual or society should at least offset the radiation detriment

Optimization:
Any radiation exposure and the number of people exposed should be kept as low as reasonable achievable (ALARA-Principe). Economic and social factors being taken into account.

Limitation:
The exposure of individuals, excluding that from medical practices should be subject to dose limits. The risks of potential exposures should be controlled.

General requirements for the application of radioisotopes in medicine are:

- License issued by the local radiation safety authorities
- Availability of proper instruments used for nuclear medicine studies and routine radiation protection measurements
- Facilities qualified for handling unsealed radioactive substances
- Qualified experts (physicians, physicists, chemists, technologists etc.)
- responsible for radiation safety

I. RADIATION PROTECTION OF PATIENTS

To evaluate the risk of nuclear medicine examinations the following dosimetric quantities have to be determined:

Dose to a specified organ
Dose to gonads

Respectively :

Effective Dose Equivalent

To reduce the dose to the patient the following measures from the medical and physical point of view have to be taken into account:

1. Precise indication including patients history
2. Take into account previous examinations to avoid unnecessary studies with radioisotopes

3. Selection of proper radio-pharmaceutical and examination protocols to minimize the radiation burden
4. Exclusion of pregnancy. If pregnancy cannot be excluded securely, the indication must be proofed carefully. The amount of activity used should be reduced to the minimum required to obtain adequate study quality. Any dose to the fetus exceeding 0,5 mSv requires careful justification, and the study should not result in a dose to the fetus of more than 1- 2 mSv. Radionuclide therapy is not indicated in pregnancy and should be avoided
5. Breast feeding females should obtain a cessation of a given time specified by the radionuclide used (12 h for Tc-99m)
6. To be sure that the positioning of the patient is correct and that there is a satisfying cooperation of the patient
7. Use of thyroid blocking agents if indicated
8. The patient should be hydrated intravenously or orally after administration to reduce the radiation dose to bladder. The patient should void the urinary bladder frequently and especially prior to imaging
9. Correct activity to be administered to obtain the necessary medical information with appropriates counting statistics. The activity has to be measured prior to administration using a Calibrated activimeter
10. Correct administration of the radio-pharmaceutical
11. Subcutaneous injection of the radio-pharmaceutical can cause ulceration at the injection site.
12. Optimization of the imaging time after application
13. Consideration of special anatomic and physiological conditions of children
14. Record and documentation of the results to allow the reading of the results at every time
15. Routine Training of Physicians and Technologists
16. Use of instruments and software according the latest state of standards
17. Routine Quality Assurance of Instruments and Radio-pharmaceuticals

Radiation Dose in Nuclear Medicine

No limits or restriction are set for diagnostic or therapeutic procedures .The effective dose equivalent from diagnostic nuclear medicine procedures is typically in the range of 1-10 mSv a Year
The dose to patients depends on the following parameters :

- **Radionuclide**

The radiation dose to the patient depends on the type of energy of radiation emitted and the physical half life of the used radionuclide

- **Chemical compound**

The radiation exposure depends on the biokinetics of the compound :
fractional distribution in organ and biological half-life .

- Mass of the organ according to the age of the individual

The dose to the patients depends on mass of the organ as shown in table :
Absorbed dose in the thyroid (AD in mGy per MBq) and effective dose equivalent (EDE in mSv per MBq)

Thyroid uptake 45% ,No blocking agents given

Age Years	mth per g	AD	EDE
1	2	6.1E+03	1.8E+03
5	7	3.3E+03	1.0E+03
10	9	1.5E+03	4.6E+03
15	15	1.0E+03	3.1E+03
Adults	18	6.4E+03	1.9E+03

- **Functional behavior of the organ taken into account**

In case of hyper thyrosis the radiation dose to the thyroid is about 56 % higher compared to normal function and in hypothyroidism 40 % lower .

- **Determination of the Effective dose Equivalent**

The effective dose equivalent H can be determined from the activity administered A in a simple way using the dose factor f of specified radio-farmaceutical

$$H=f*A$$

II. RADIATION PROTECTION OF THE STAFF

Handling of radioactive material involves radiation risks to members of a staff engaged in nuclear medicine (physicians, health physicists, chemists, technicians, nurse's etc.) from:

External radiation

In the presence of an unshielded radioactive source or a patient after administration of radioactivity

Internal radiation

Intake of radioactivity into the body by oral ingestion (eating, drinking, smoking), inhalation and through the skin.

III. Radiation Protection of the General Public and the Environment

Patients are part of general public
Methods to optimize the radiation protection of the general public are

- Sufficient radiation shielding or distance to buildings and rooms of the general public
- Prevention of discharging of radioactive material from nuclear medicine facilities to the environment
    - Use of decay and retention plants for radioactive fluids and gases
    - Use of filters in the ventilation system
- Radiation monitoring
- Special waiting rooms for patients after administration of radioactive substances
- Hospitalization of patients treated with radionuclides in nuclear medicine therapy
- Restriction in discharging of treated patients
- Restrictions in application of radioactive substances in medical research on volunteers
- Members of the general public in nuclear medicine research

Methods to optimize the radiation protection of the general public in nuclear medicine research are:

1. Requirement of license issued by a radiation protection authority
2. Limitation of the number of volunteers
3. Determination of the radiation dose to patients and volunteers
4. Limits of the radiation dose of volunteers
5. Restriction in selection of volunteers
6. No administration of radioactive substances to pregnant or breast feeding females
7. No administration of radioactive substances to children
8. Survey of a authorized expert
9. Vote of an ethic commission
10. .Agreement of patients and volunteers with examinations to be carried out
11. Recording of the results and reporting them to the authority

Conclusions

The risk involved in applications of ionizing radiation and radioisotopes in medicine to patient have to be weighted against the advantages. Optimization of regulations and methods in radiation safety may prevent or minimized radiation hazard to patient ,members of the staff and individuals
of the general public .All persons engaged in the application of ionizing radiation in medicine are responsible to fulfill requirements to optimize radiation safety .

Reference : Optimization of Radiation Protection in nuclear Medicine . J.Kretscho

THE PATIENTS DOSES IN ROENTGEN DIAGNOSTIC EXPOSURE IN BELARUS

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Abstract

We describe the situation with patient doses from roentgen diagnostic situation in Belarus. We pay attention mainly to fluorography of lung in health patients applied for discovery of tuberculosis. The equipment in our country is far from modern but use very intensive in clinic practice.

The structure of X-ray investigation is discussed.

We used the usual method of entrance dose determination: TLD measurements with LiF detectors disposed in center of radiation field of units. The object of irradiation were Alderson-Rando phantom and patients. The "NOMEX" dosimeter has been used for phantom measurements also.

The mean entrance dose for lung changed from 4 to 16 mGy for fluorography and from2 to 10 mGy for stationary units without automatic image processors.

The effective dose for exposure changed from 0.7 to 6.5 mSv and means 2.5 mSv.

The collective effective dose for Belarus population is about 14 000 Sv a year. This number 20 times more then collective effective dose from Chernobyl accident irradiation.

The ways of dose decreasing are discussed. There are refusing from "wet" processing of films, creation a new equipment without film using. Such X-ray unit was worked out in 1998 and began to work in Belarus hospitals widely from 1999.

Introduction

The roentgen diagnostic investigation can be divided on two classes: prophylactic and medicinal. The prophylactic investigations of healthy people are realized in our country for revealing the tuberculosis of lungs mainly. The others are realized in clinics for patients with different illness for diagnosis specification, for the area determination of pathological process distribution, for the treatment effect evaluation etc.

The structure of roentgen diagnostic equipment.

The number of roentgen diagnostic units in Belarus was about 2600 in 1999. The stationary units were 1038 (41%), fluorography units - 433 (17%), moving, and dental units - 1016 (42%). 360 stationary units (34.6% from all stationary complexes) had been completed by image intensifiers. Belarus has 17 CT only.

The most of stationary roentgen units were RUM-20 (450 comp.) from Kazakhstan, EDR-750 from Hungary and TUR (East Germany) - more then 100 complexes every. The time of life was less 5 years for 8% of units, from 5 to 10 years for 33%, from10 to 15 years for 27% and more then 15 years for 32% from the whole number of diagnostic equipment. The normative time of clinical using of this equipment is 10 years in Belarus.

The medical investigation structure.

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The largest number of exposures is fluorography (56% from the whole number of investigations). The investigations in stationary roentgen units are distributed the next: chest organs 15%, bones and joints - 14%, teeth -9%. The most radiation dangerous angiography - 0.5% only. The very important peculiarity of the diagnostic work is fact that 20% of equipment disposed in large clinical centers is used in 70% investigations, and other 30% of investigations are conducted on 80% of equipment disposed in small hospitals. The main diagnostic work in small hospitals is fluorography. The large clinics conduct most of investigation and form the main part of patient collective effective dose in population.

What dose limits for patients are in diagnostic irradiation?

These limits were absent in Community of the Independent States (CIS) before 1997. Only in 1997-1998 in some countries state laws were accepted and radiation safety standards also. On these standards the limit of effective dose for healthy people is 1 mSv a year. International Atomic Energy Agency (IAEA) in 1996 included in International Basic Safety Standards №115 [1] the entrance dose limits for different kinds of roentgen diagnostic exposures. The acceptance of these limits is result of large experience of the developed West countries where such limitation was accepted in 80th and permitted to decrease the patient doses.

We have led the investigation of patient doses in different roentgen exposure in Belarus. We have the supporting of this work from Belarus Ministry of Public Health.

Materials and methods.

We have measured the entrance absorbed dose in the center of entrance radiation fields on Alderson-Rando phantom and patients also. The thermoluminescent detectors from LiF of Latvian production were used. The "NOMEX" dosimeter from PTW-Freiburg was used for measurements on phantom. The main ionization chamber was 7734 with volume 1 cm^3. LiF-detectors and ionization chamber were calibrated in X-ray facility of Belarus SSDL. The energy sensitivity was calculated and used in dose determination.

The equivalent dose for separate organs and effective dose were calculated by program "ORGDOSE" created out in Russian Central Research Roentgenology and Radiology Institute (CNIRRI) in Sent-Petersburg together with specialists of STUK (Finland) [2]. This program was tested in Scandinavian countries and now is distributed in Finland as PDS-60. The Finnish company "RADOS" distribute this soft in the Europe. The CNIRRI distribute soft in (CIS).

Results and discussion.

The measurements were conducted in 7 clinics on 15 fluorography units and 15 stationary roentgen units.

Results of investigation showed that technology of patient irradiation and image processing in our country didn't permit to receive the entrance doses lower then IAEA limits on all units. The entrance doses in lung investigation for all fluorography units were in limits from 4 to 16 mGy. The IAEA limit for this exposure is 0.4 mGy. The entrance doses on stationary roentgen units changed from 2 to 10 mGy.

In developed West countries: USA, UK, France, Germany, Finland and others the mean entrance doses are in limits 0.05 – 0.2 mGy for lung investigations [3]. It is connected with fact that the necessary laws about radiation protection of medical exposure were accepted in these countries earlier then in ours. The different medical professional societies, companies-producers of the equipment had to create out the special actions for decreasing the patient doses in roentgen diagnostic. These actions are very expensive, but public health is mach more expensive, therefore problem was decided quickly and firmly. At first, the

decision was accepted to refuse from fluorography of healthy people on old techniques and refuse from old methods of image processing. Really the fluorography in West countries was interdicted in practice. The main action in roentgenography was obligatory using of automatic image processors.

We had checked the possibilities of image processors for dose decreasing on stationary units in comparing with the usual "wet" process and have got the next results: the entrance dose have decreased 5-6 times. In a new stationary units "Siregraph" (Siemens) the entrance dose decreased to 0.3-0.4 mGy that corresponds to IAEA limits. Even 10-15 years old units with new automatic processors decreased the entrance doses to 0.3 – 0.5 mGy that near for IAEA limits. Unfortunately we have in country no more then 40 automatic processors.Calculation of effective doses in fluorography lung investigations have showed obviously bad picture in Belarus. These doses are disposed in limits from 0.7 to 6.5 mSv. The mean dose is 2.5 mSv for one exposure. Remember that the Belarus standard requires no more then 1 mSv a year. The collective effective dose for Belarus population (10 millions inhabitants) is about 14 000 Sv. On the stationary units with automatic image processors we received 0.3 – 0.4 mSv for lung exposures. It's in action even for 10 years old units.

The investigations of other organs: abdomen, pelvis, spine and etc. are applied only for sick patients, then we have no limits for effective doses in such cases. As a rule the entrance doses in these investigations in 20 times and more upper and IAEA limits upper then in case of chest exposure also. These limits can be endured only with automatic image processors using. In connection with our investigation we need to recalculate the estimations of effective dose for patient roentgen exposure published in 1991 for USSR and Belarus by R. Stavitsky, F. Lyass and others [4], where they showed the mean effective dose for patient in Belarus 1.3 mSv a year. Our data this dose is disposed between 3 and 4 mSv. If we use their data about cancerigenic risks from roentgen exposure $4 \cdot 10^{-2}$ Sv^{-1}, we can received 1200-1600 new patients with radiation-induced cancer every year. This number is about 4-5% of all new cancer patients in country. During 30 years, if we don't change this situation, we will find about 36000-48000 new cancer patients. This number is approximately 20 times more then number of cancer patients from Chernobyl accident in the same 30 years.

Now the large work is conducted in Belarus on liquidation such situation. The special digital fluorography units have been created out for changing of usual old equipment. This units "PULMOSCAN-760" has CsJ (Tl) array detector with 760 elements which moves synchronously with narrow X-ray beam through the lung zone [5]. This device is serially produced from 1999. The entrance doses for lung on this unit in usual regimes of work are about 2-5 μGy, and effective doses are about 2–3 μSv. During 1999-2000 more then 45 units were installed in Belarus.

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LA PROTECCION RADIOLOGICA EN LOS MEDIOS HOSPITALARIOS DE GUINEA ECUATORIAL*

*Por PRAXEDES RABAT MACAMBO***

I. ABSTRACT

A population with (400.000) four hundred thousand inhabitant and distributed in territory (28.000) 28 thousand Km², the useness of ionizing radiations for medical practice in Equatorial Guinea is smallest only decreased and used for diagnostic practices in the main hospitals of the country, where the work burgden is not over 20 patients for day.

The political, social and economical embryonic development of the country untill recent dates it had an negative influence for indicators and health organisations, so that even now the country not have any radiological protection law, this shortness, in addition with the old architectural structure that x ray tools is logding, as well as dosimetrical lacke for employed staff, it put this staff under risk of electromagnetic energy.

This is to show the present survey of medical activities with ionizing radiations and to request technical support for implement suitably the basic standards of anti-radiation protection which will help us as basis for the elaboration outline law, on radiological protection in accordance with the new guidelines of international organization for Atomic Energy.

Guinea Ecuatorial es un país situado en Africa Central y tiene fronteras terrestres con Gabón y Camerún, así como fronteras marítimas al Norte de la Isla de Bioko con Nigeria.

Para una superficie total de 28.000 km², este territorio se divide en dos regiones : una continental, de 26.000 Km², y otra insular, Bioko, con 2000 Km² y en la cual hallamos la ciudad de Malabo, capital política del país. Con una población de poco más de 400.000 habitantes, los principales indicadores de salud de su población en 1999 eran de :

Esperanza de vida al nacer : 49,8%
Tasa de mortalidad infantil : 87 ‰

Tras acceder a la independencia en 1968, el país fue sumido en una de las dictaduras más crueles y sanguinarias del mundo, lo cual trajo consigo la huida de los pocos intelectuales, médicos, políticos, etc. La Administración del Estado y, consigo la Administración de Salud se vieron expuestas a los peores desórdenes burocráticos, y a la desaparición masiva de sus archivos. Esta situación conllevó a que tras la restauración de la democracia once años después, nada se pudo encontrar en los archivos del Ministerio de Sanidad referente a la protección radiológica en el campo de la medicina.

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* *Sesión técnica : Cuestiones especificas de la protección radiológica ocupacional*

* **Adjunto del Jefe de Servicio de Radiodiagnostico. Hospital General de Malabo. Técnico Radiólogo y Diplomado en Ecografias por el C.H.U de Tours, Francia. Coordinador Nacional en materia de Protección Radiológica.*

Los Servicios de Radiología que han sido objeto de este estudio han sido nuestra única referencia para iniciar una tímida reglamentación de las normas básicas y prácticas de protección radiológica para los Servicios de Radiología de los hospitales del País.

Estos servicios se caracterizaban, en términos generales, por su diseño arquitectónico colonial, pero que se adaptaba perfectamente a las condiciones climatológicas locales y a las condiciones de irradiación, es decir :

> Salas amplias y altas : la única sala de rayos X del Hospital General de Malabo tiene 14 x 9 metros, con lo cual el operador se halla a más de 6 metros de la fuente principal de irradiación.
>
> La sala de rayos X del Hospital de Luba, a 56 km de Malabo ; y la de Bata, en la región continental, a 300 Km, presentaban similares características.

Estas salas no presentaban suficiente protección de los muros, ventanas y puertas, aunque según recomendaciones de los manuales de la OMS, en países con escasos recursos, es más rentable construir unas salas de dimensiones ligeramente superiores en lugar de comprar material plomado para proteger muros y ventanas[1].

Con esta medida se pretende aplicar el principio de que la irradiación se reduce en función al cuadrado de la distancia[2]. Además, teniendo en cuenta que por lo general cada uno de estos servicios atiende hoy día a menos de veinte (20) pacientes por día, y con radiografías simples de tórax y extremidades; de vez en cuando se realizan pruebas contrastadas gastrointestinales (3-4/semana) y urológicas (2-3/semana), estimamos que los riesgos de una sobreexposición de pacientes y operadores son mínimos.

A pesar de ello, constatamos que nuestros Servicios de Radiología presentan ciertas deficiencias, a veces tan elementales que podemos considerarlas como graves :

> Ningún operador del país trabaja con dosímetros personales, porque no los hay.
> Los delantales y guantes plomados, o son insuficientes, o son deficientes, o no existen en ciertos Servicios de Radiología.
> La extensión de los parabanes con cristal plomado, muchas veces, es deficiente como para proteger a los operadores.
> No existe un Departamento que se encargue de evaluar las dosis recibidas por los pacientes y operadores, y por lo tanto, el personal profesionalmente expuesto a las radiaciones ionizantes, así como el público en general, están corriendo los riesgos inherentes a una exposición radiológica no controlada.
> La baja cualificación profesional de muchos técnicos y auxiliares de radiología, la negligencia de éstos en la observancia, cuidado y control de las normas de protección radiológicas elementales, ya sea por olvido o por falta de suficiente información actualizada al respecto, les exponen constantemente a los peligros de una sobreexposición a las radiaciones. Téngase en cuenta que la dósis de irradiación

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[1] KLECZKOWSKI, B.M ; PIBOULEAU, R. : Planification et conception des équipements de santé dans les régions en développement : approches possibles. OMS, publication offset n° 45. Genève, 1980.

[2] Gárate Rojas, M. : Fundamentos de la Técnica Radiográfica. Ed. AGFA-GEVAERT, Barcelona, 3a ed., 1991.

recibida por los técnicos y médicos radiólogos varía considerablemente según los reflejos de radioprotección que éstos habrán sabido o no desarrollar [4]

Una de las primeras medidas que tomó el primer grupo de técnicos radiólogos cualificados egresados al país en 1987 y tras verificar que no existía normativa alguna para la protección del personal ocupacionalmente expuesto a las radiaciones ionizantes, así como de los miembros del público, fue elaborar, hacia 1990, un Anteproyecto de Ley sobre Protección Radiológica, que fue propuesto a las Autoridades del Ministerio de Sanidad. Lamentablemente, este Anteproyecto de Ley no siguió su curso ni fue aplicado, y tuvimos que esperar hasta 1993 para ver un primero pero tímido intento de regular, por parte del Ministerio de Sanidad de Guinea Ecuatorial, cierta normativa encaminada a controlar las actividades relacionadas con las radiaciones ionizantes.

Dicha normativa, que nunca ha tenido rango de Ley, es la que se viene aplicando hasta hoy y se caracteriza, dada la poca experiencia de los redactores de la misma, por una reglamentación de embrionaria aplicabilidad y que, hoy en día, no se adapta ya a las nuevas directrices de los organismos internacionales de Energía Atómica.

Por todo cuanto antecede, solicitamos de las instancias aquí presentes, un asesoramiento en el aspecto técnico y legislativo encaminado a garantizar las normas de bioseguridad radiológica, introduciendo medidas de seguridad suplementarias en los edificios, instalaciones, uso, reparación y eliminación final del material[3]. Estas medidas coadyuvarían a que se elaborase y se promulgase una Ley de Protección Radiológica de aplicabilidad nacional.

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[3] Arias C.F ; Skvarta J.J. : La protección radiológica en Medicina ; in : 100 años de Radiología, Revista de la Organización Mundial de Salud ; n°3, Mayo-Junio de 1995.

4 **Herbelet,** G.: Exemples d'exposition du personnel, in: Rayonnements ionisants et Radioprotection, en la revista " Le Manipulateur" , N° Especial, Ed.: A.F.P.P.E, Paris, Septiembre de 1999.

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Topical Session: Radiological protection of the fetus (in pregnant patients)
Title: Patient and fetal dose in diagnostic x-rays and radiotherapy in Bangkok, Thailand.

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Abstract

In 1999 the multicenter study of the patient surface dose has been conducted at Department of Radiology of Chulalongkorn Hospital, another two university hospitals and a hospital in the suburb. Adult female patients were selected to measure the entrance skin dose and accumulated dose by using the thermoluminescent dosimeters and the kerma area product meter respectively. The fetal doses were calculated by Monte Carlo method using the computer program written by Le Heron J.C. The average fetal doses were studied for each diagnostic radiographic procedure. The fetus got 0.29, 0.35, 2.63 mGy when their mothers had radiography of pelvis, lumbosacral spine, excretory urography respectively. The estimated fetal doses for barium meal, barium enema and renal angiography were 1.47, 33.5 and 3.68 mGy respectively. The fetal dose varies so much about 2-3 times of the average fetal dose due to equipments and techniques. The study of lower abdomen by computed tomography gave 48.4 mGy in average to a fetus. The scattered dose level outside radiotherapeutic x-rays at fetal position in Rhando phantom depends on the primary beam area rather than the energy of radiation. If the threshold dose for fetal malformation is 0.1 Gy, the minimum safety distance for him is 22 cm from beam edges for the tumor dose of 60 Gy .

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I. Introduction:

After three young workmen died within three months after the exposure of the unshielded Co-60 source (560 Ci) at the outskirt of Bangkok, in February 2000. Most Thai people were alert of radiation hazard and protection. The medical physicist was asked to evaluate the conceptus dose more often than before. This report presents data of current levels of radiation dose to patients and fetuses.

Most Departments of Radiology in Thailand performed the radiation protection for the patients as follows:

1. Set quality control of the x-ray machines in diagnostic studies, including teletherapeutic machine, the brachytherapy units and those instruments in nuclear medicine. Radiation survey is performed around each machine, under conditions that yield maximum exposure rate.
2. Technologists use proper procedures of radiological technique for small amount of the patients' radiation exposure.
3. Provide the lead apron or gonad protector for the conceptus outside of x-ray beam. An 8 cm of Cerrobend is used to minimize the fetal dose for the pregnant woman during the treatment of tumors.[1]
4. Warning signs of radiation protection for the child bearing age patients are put on the door of entrance as shown in fig.1.
5. Guidelines on safe practice for female patients (~ 12-50 y) who have abdominal or pelvic radiographs, special procedure of lower abdomen and nuclear studies are recommended as followings.
    a. A brief menstrual history includes age of menarche, regularity or duration of menstrual cycles, the date and duration of the last normal menstrual period.
    b. When patient data is unclear, the radiologist should question the patient about possible pregnancy. The symptom suggestion of pregnancy should be followed with a urine pregnancy test. The pelvic examination can confirm pregnancy around 8-10 weeks.
6. Dose assessments in diagnostic radiology are listed and conceptus doses are calculated in order to understand the potential detriment of various exposures. Expression of malformation in a conceptus depends on the proportion of differentiating cells and the rate at which cellular injury, while the radiation effects depends on the dose and dose rate of exposure. The ICRP[2] assessed the risk of radiogenic mental deficiency at 0.4/Gy during the age of 8-15 weeks while the NEA[3] stated the proportionality coefficient of 7-13 IQ points decrease per Gray.

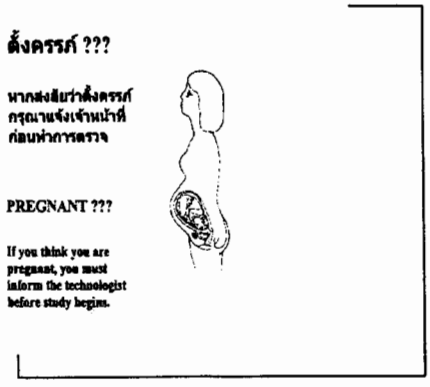

Fig.1. Notices in Thai and English for the child bearing age patients before having radiological examination and treatment.

II. Aims and objectives

A. To access the current levels of patient surface dose in different diagnostic roentgenological procedures and calculate the fetal dose using Monte Carlo method.
B. To monitor dose outside therapeutic beam at fetus position and normalize to the infield dose for calculation of fetal safety distance.

III. Materials and Methods

A. Dose assessment for patients and the conceptus:

A.1 Adult female patients of 50-75 kg in weight, who underwent diagnostic roentgenological examinations in the outpatient department of four hospitals were studied for radiation dose measurement. The study was performed at three university hospitals in Bangkok and one general hospital in suburb. Patient doses were monitored for the examination of lumbosacral spine, pelvis, intravenous urography, barium enema, barium enema, renal angiography, chest and abdominal computed tomography. The accumulated doses were measured using the plane-parallel plate ion chamber and the Diamentor E. The TLD-100 chips were used for measured the computed tomography dose index (CTDI)[5].

A.2 Fetal doses were calculated by using the program named XDOSE and CT DOSE which written by Dr. J. Heron, National Radiation laboratory, New Zealand. These programs were a part of a software report NRPB-SR250 and NRPB-SR262, the calculation of organ doses by Monte Carlo calculation. These programs were distributed by the IAEA for the research project on the diagnostic x-rays in Asia.[6]

A.3 Dose measurement outside the 6 and 10 MV x-ray beam were done in Rhando phantom at fetal position using TLD-100 chips and a TLD reader, Harshaw model 5500. [7,8]

IV. Results and observations

A. Diagnostic x-rays

The primary study of adult female patient surface doses, various types of radiological examination were shown in Table 1-2-3. The number of sample for renal angiography was low because there was few cases/year. The doses depend on the equipment used, the size of patients and the methods used by radiologists in performing the study. The average fetal dose is calculated for x-rays 80 kVp, 3.0 mm.Al HVL. The results show fetal doses from lower abdominal CT and fluoroscopic studies are high. No reference doses for patients in South-East Asia to be compared.

Table 1. Patient surface doses of female adults from four conventional radiological types in Thailand, 1999

X-ray Exam.	No Observ.	Tube voltage (kV)	Min	1st quartile	Median	Mean	3rd quartile	Max	av. fetal dose (mGy)
			Absorbed dose (mGy)						
LS AP	23	60-85	0.42	0.76	1.35	1.41	1.83	3.46	0.35
LS R. LAT	27	70-90	1.34	1.76	2.85	4.47	6.03	16.1	0.09
Pelvis AP	22	60-85	0.38	0.54	0.72	1.01	1.18	2.16	0.29
IVU	24	63-73	4.42	6.63	8.97	10.4	13.0	19.7	2.63

Table 2. Patient entrance doses of female adults from fluoroscopic examination

X-ray Exam.	No Obs.	Tube voltage (kV)	Min	1st quartile	Median	Mean	3rd quartile	Max	av. fetal dose (mGy)
			Absorbed dose ($Gy.cm^2$)						
Barium meal*	20	80-100	9.34	38.02	53.87	59.43	82.72	128.5	1.47
Barium enama*	24	80-100	18.74	40.7	79.43	77.42	91.71	196.0	33.5
Renal angio**	6	80-100	38.54	-	130.7	140.4	-	279.9	3.68

* Using Toshiba KXO/80N, Siemens Sireskop,

** Using Siemen Neurostar Plus operated in digital pulsed mode.

Table 3. Patient doses of adults from CT examinations* in Thailand, 1999.

CT Exam.	No Observ.	Tube (kV)	mAs	slice width (mm)	no of slice	av. fetal dose (mGy)
Chest	15	120	234-340	10	28-57	0.09 ± 0.04
Whole abdomen	15	120	234-340	10	29-103	48.4 ± 16.4

* Using GE Sytec 4000, GE 9800Q, Philips Tomoscan CX/Q

B. Radiotherapy

The data presented in Table 4 is the dose outside a beam from Varian Clinac 1800 S/N 237 in the pelvic wall of female Rhando phantom. This data is similar to the total absorbed dose in phantom at 10 cm depth reported by the AAPM[9] in 1995. The safety distance for fetus developing malformation was calculated. If a fetus is too closed to a beam edge, the shielding is required. For megavoltage x-rays, the scattered doses depend on the area of primary beam rather than photon energy [7].

Table 4. The average scattered dose to fetus in Rhando phantom normalized to the peak dose at central axis using TLD.

Energy (Machine)	Field size (cm)	Distance from beam edge 2.7	5	10 (cm)	Safety distance for malformation*
6-10 MV Clinac 1800	10x10	10%	2%	0.6%	more than 22 cm
	20x20	20%	5%	1.2%	more than 28 cm

* The tumor dose is 6000 cGy and the threshold dose for malformation is 10 cGy.[10]

Discussion and conclusion

Fetal doses are high in both barium enema study and the whole abdominal CT but it is less than the threshold dose for malformation in the first trimester period. The maximum fetal dose may be 2-3 times of the average fetal dose. The reference doses for patients in South East Asia should be set up. For radiotherapy, scattered doses are similar to those reports by other investigators.[11,12,13]

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PRESENT SITUATION AND DEVELOPMENT PROSPECTIVE OF THE NUCLEAR MEDICINE IN KAZAKHSTAN.

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Abstract. The nuclear medicine has the less spatial resolution in obtainable medical images as compared with other kinds of radiology, but it has a unique power of determining the functional disabilities of the different organs and physiological systems without some clinical symptoms, and thus it has permitting to conduct timely diagnosis of the illness during the its early stages. This characteristics and other abilities of the radioisotope diagnosis has a noticeable place in a general row of clinical diagnostic methods. The nuclear medicine remains for the some pathological conditions the exclusively method of necessary information receiving. The nuclear medicine methods allow determining the functional and morphological changes with high degree of precision at earlier phases of most diseases and defining nature and direction of treatment. Taking into consideration big diagnostic capabilities of radionuclide methods, we witness increase of the number of nuclear diagnostic laboratories in various countries every year.

The main result of the development of nuclear medicine in the Republic of Kazakhstan is its evolution as an independent scientific clinical discipline. The present situation in the field of the using of nuclear medicine is described in this paper.

The nuclear medicine in Kazakhstan reached its peak at the beginning of 80s when every regional center and every clinical center in Almaty (the former Capital of Kazakhstan) had a radioisotope laboratory. The total was 27. In the former Soviet Union there was the state technical service and network of radiopharmaceuticals supply from domestic producers (Russia, Uzbekistan).

Using of the nuclear medicine is very actual for Kazakhstan, because the major factors responsible for the generation of radioactive situation in the country includes uranium mining and milling activity, mining and milling of commercial minerals containing radioactive elements and underground and atmospheric nuclear explosions for military and peaceful purposes [1]. According to the official data the number of citizens lived in the radiological dangerous areas or been affected by radiation due to their professional duties is 6% of population of the country. Additionally more than 30 thousand peoples participated in the liquidation of Chernobyl accident consequences. As patients all of their needs the favor diagnosis methods connected with using of radiation. Using of short-life isotopes in radioisotope laboratories and modern high-technological equipment is the better way for solving of this problem.

Unfortunately after the disintegration of the former Soviet Union we can look the regress in above area. It is connected with the economical situation in the countries of CIS, because some relationships between former Soviet republics were destroyed. Since this time the radioisotope supply was actually stopped, and so did stop the activities in the laboratories. Lot of specialists left their work places and due to that currently there are only 12 operate laboratories. The equipment mainly produced in

Hungary during 1971-1983 is outdated. Only one gamma camera made by ADAC Company operated in the Republican Clinical Hospital for Invalids of World War II (RCH). It was received by supporting of the government of Japan and operated since 1998.

Also the important fact is that for the last 10 years many doctors actually "forgot" this diagnosis method due to the appearance of ultrasound diagnosis and computer tommography, and currently this method is left fully unclaimed.

New stage in the development of nuclear medicine in Kazakhstan was started in October 1998. The IAEA Regional Training Course connected with the problem of Nuclear Medicine was conducted on the base of RCH for participants from West Asia countries. Two national seminars during 1999-2000 were conducted by supporting of IAEA. That made the possibility of the recreation and improving of this part of medical service in Kazakhstan. The assistance of international experts allowed recreating and back to work 5 of 10 existing gamma cameras, which were not used in hospitals during the last 5-7 years. Thus, as the result of this work is the start of operating of four nuclear medicine laboratories.

For example, research functions of nuclear medicine laboratory in RCH equipped with "ADAC" gamma-camera were expanded by supporting of IAEA, and currently hospital's laboratory use all ***in vivo*** and ***in vitro*** searching methods. Those are used for study of small dozes of ionized radiation influence on the people's health. It is conducted the diagnostic in early stages to determine topographic, anatomic, and function conditions of organs, as they are the most informative and least hazardous in terms of radiation exposure for the patient. For example, that are conducted dynamic and static scintigraphy of kidneys, liver, thyroid gland, radioisotope X-ray, myocardial scintigraphy of skeleton, testicles, and brain, which allowed determination of the typical morphological functional changes in these organs.

Methods of computing and analysis of nuclear medicine results are actively being developed. Here there are several strategic directions: necessity of high quality image creation, reduction of time length of reconstruction process, development and application of new diagnosis methods and modern equipment. For example it is the implementation of PIP Gamma-PF system, provided by IAEA for clinical practice of Almaty laboratories, which allowed improving quality of radioisotope services.

The approach of computerizing of all technological processes in division is highly important for increase of the work effectiveness. Using of the appropriate software packages for the forming and computing images, for calculating of injected activity and radiation load on a patient, control of supply and utilization of radiopharmaceuticals, for unifying and increasing of medical documentation quality are very actually and useful. Computer system for archiving and transmission of data are developed, local area computer networks and radiological databases are created, which are highly effective for increasing of diagnosis precision and for education and training of the personnel.

One of the important task for the development of the nuclear medicine is the own production of radiopharmaceuticals for diagnosis and therapy [2]. Currently the situation in this matter is not so good, because before the getting of sovereignty Kazakhstan hadn't the own industry for production of radiopharmaceuticals. In the new condition of the independence the country has to import the radiopharmaceuticals and this process accompanied by some difficulties such as high cost, transport problem etc. Therefore Kazakhstan need to development of the production of radiopharmaceuticals. And in this case is very important the role of IAEA. Under

some IAEA Technical Co-operation projects the National nuclear Center of Kazakhstan started organization of production and application to clinical practice generator systems Molybdenum 99 – Technetium 99M. As the institutions of NNC had receive the modern equipment and have high quality personnel, it is a good start for the future.

Thus above mentioned factors are the basis for development and improvement of activity for nuclear medicine laboratories in Kazakhstzn. Further development and prospective of nuclear medicine at current period are defined by solving of the following problems:

1. Development of own production of short-life radioisotopes and radiopharmaceuticals using in nuclear medicine.
2. Increasing qualification of specialists in nuclear medicine laboratories.
3. Setting up the National Education Center for the nuclear medicine specialists on the base of RCH with the assistance of IAEA.
4. Attracting for collaborative research activity in the field of nuclear medicine specialists from the develop countries.
5. Implementation of new methods and development of more sophisticated methods for diagnostics of pathological processes in various organs and functional systems.
6. Introducing to the clinical practice new radioisotopes and radiopharmaceuticals.
7. Improving the process of storage and transmission of collected data.
8. Creating of the illustrated clinical protocols, which can meet the current requirements. Providing the nuclear medicine diagnosis for all needing patients.

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NUCLEAR MEDICINE AND ITS RADIOLOGICAL PROTECTION IN CHINA

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[Abstract] The China Society of Nuclear Medicine was established in 27 May, 1980. Since then, nuclear medicine in clinical diagnosis and therapy has been developed rapidly in China. So far there are more than 4000 members of the Society, and more than 350 sets of SPECT and 12 sets of PET have been installed and are busily running in clinic nowadays and about 1 million patients with different types of diseases have obtained nuclear medicine imaging examinations per year. Concerning the nuclear medicine therapy, a lot of patients with many types of diseases obtained benefit from radioisotope therapy. Accordingly, several Policies and Regulations have been enacted by the Government for the radiological protection. Furthermore, a special book titled as "Standardization in Diagnostic and Therapeutic Nuclear Medicine" has been promulgated in June, 1997 by the Health Administration of People's Republic of China,and this book is distributed to almost every nuclear medicine physician and technician in China for their reference in routine nuclear medicine work or research. In this book three parts of contents are covered: Policies and Regulations for the radiological protection, basic knowledge and clinical nuclear medicine applications.

1. Nuclear Medicine Imaging

Radionuclide scintigraphy is a diagnostic method that provides high sensitive and specific images of the distribution of radionuclides in the human body. The radiolabeled compounds used include substrates, ligands, drugs, antibodies, neurotransmitters and other biomolecules that are tracers for specific biological processes. Thus the resulting images can be considered images of these biochemical or physiological processes(often called "functional images"). Accordingly, this imaging technique has been widely used in clinic, especially used in oncology, cardiology, neurology,.... The China Society of Nuclear Medicine was established in 27 May, 1980. Since then, nuclear medicine has been developed rapidly in China. There are more than 4000 members of the Society so far, and more than 350 sets of SPECT, 12 sets of PET(includes 8 PET centers) up to now are busily running and about 1 million patients per year have received nuclear medicine imaging examinations in China.

2. Radioisotope Therapy

Radioisotope therapy, an innovative and promising approach, based on lesion-targeting radiopharmaceuticals, which can potentially be used as powerful carriers of large amounts of radiation for treatment of many types of diseases, such as hyperthyroidism, metastases or recurrence of thyroid cancer, and many other types of cancer. Therefore, this therapeutic methodology nowadays has been widely utilized in clinic in China.

3. Policies and Regulations

In the purpose of radiological protection in safe medical application of radioisotope in nuclear medicine, several Policies and Regulations have been enacted by the Government, including:

- Drug Management Policy of People's Republic of China;
- Execution Method of Drug Management Policy of People's Republic of China
- Management Regulation of Radiopharmaceuticals;
- Radiological Protection Byelaw on Radioisotope and Radio-facility;
- Radiological Protection Standards in Clinical Nuclear Medicine;
- Standards on Radiological Protection of Patients in Clinical Nuclear Medicine.

Furthermore, a special book titled as "Standardization in Diagnostic and Therapeutic Nuclear Medicine" has been promulgated in June, 1997 by the Health Administration of People's Republic of China and distributed to almost every nuclear medicine physician and technician in China for their reference in routine nuclear medicine work or research. Three parts are covered in this book:

- Policies and Regulations which are mentioned above;
- Basic knowledge, including:
  - principle of construction of nuclear medicine department;
  - radiological protection;
  - radiopharmaceuticals;
  - nuclear medicine instrument;
- Clinical Nuclear Medicine application, which mainly includes:
  - routine radionuclide imaging of most organs with the contents of imaging mechanism, clinical indication, radiotracer, imaging protocol, normal and abnormal images, clinical values, and demands of imaging report writing;
  - radioisotope therapy with the contents of therapeutic mechanism, clinical indication and taboo, protocol, and therapeutic effective comments;
  - radioimmunoassay.

In the part of clinical nuclear medicine application mentioned above, the guidance radiological dose for each imaging and therapy is recommended, most of which are listed as follows and very beneficial to radiological protection of patients.

Table 1. **Guidance dose in diagnostic nuclear medicine**

Examined organ	**Radionuclide**	**Radiopharmaceutical**	**Reference dose**
bone	Tc-99m	MDP	555-740MBq(15-20mCi)
kidney	I-131	OIH	11.1-18.5MBq(0.3-0.5mCi)
	Tc-99m	DTPA	370-740MBq(10-20mCi)
	Tc-99m	EC	370-740MBq(10-20mCi)
	Tc-99m	DMSA	185-370MBq(5-10mCi)
	Tc-99m	MAG_3	370-740MBq(10-20mCi)
thyroid	Tc-99m	TcO_4	74-185MBq(2-5mCi)
	I-131	NaI-131	1.85-3.7MBq(50-100μCi)
Thyroid cancer metastases	I-131	NaI-131	74-185MBq(2-5mCi)
brain	Tc-99m	ECD	740-1110MBq(20-30mCi)
	Tc-99m	HMPAO	740-1110MBq(20-30mCi)
	F-18	FDG	185-300MBq(5-8mCi)
Lung perfusion	Tc-99m	MAA	111-185MBq(3-5mCi)
Lung ventilation	Tc-99m	DTPA	1110-1480MBq(30-40mCi)
Lung tumor	Tc-99m	MIBI	740-925MBq(20-25mCi)
Lung tumor	Tl-201	$TlCl_3$	101-185MBq(3-5mCi)
Heart function	Tc-99m	RBC	740-925MBq(20-25mCi)
Cardiac perfusion	Tc-99m	MIBI	555-740MBq(15-20mCi)
Cardiac persfusion	Tl-201	$TlCl_3$	74-111MBq(2-3mCi)
infection	Tc-99m	WBC	370MBq(10mCi)
infection	Tc-99m	HigG	370-740MBq(10-20mCi)
infection	Ga-67	Ga-67 Citrate	74-185MBq(2-5mCi)
liver	Tc-99m	Colloid	148-296MBq(4-8mCi)
liver	Tc-99m	EHIDA	185-370MBq(5-10mCi)
Liver blood flow/pool	Tc-99m	RBC	740MBq(20mCi)
lymph	Tc-99m	dextron	74-222MBq(2-6mCi)
Bone marrow	Tc-99m	colloid	555-740MBq(15-20mCi)
tumor	F-18	FDG	259-370MBq(7-10mCi)
tumor	Ga-67	Ga-67 Citrate	74-185MBq(2-5mCi)

Table 2. **Guidance dose in therapeutic nuclear medicine**

Treated organ	**Radionuclide**	**Radiopharmaceutical**	**Reference dose**
hyperthyrodism	I-131	NaI-131	**
Metastases of thyroid Ca	I-131	NaI-131	2.96-7.4GBq(80-200mCi)
Bone metastases	Sr-89	$SrCl_3$	148MBq(4mCi)
Bone metastases	Sm-153	Sm-153 EDTMP	740-1850MBq(20-50mCi)
Artery intervention of tumor	P-32	P-32 microsphere	1.85-7.4GBq(50-200mCi)
Neuro-endocrine tumor	I-131	I-131-MIBG	3700-7400MBq(100-200mCi)

** Dose=[(70-120μCi/gram of thyroid)×gram of thyroid]/I-131 uptake of thyroid

TRENDS AND THE DETERMINATION OF EFFECTIVE DOSES FOR STANDARD X-RAY PROCEDURES

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ABSTRACT

Trends in the entrance skin exposures (air kerma) for standard x-ray imaging procedures are reported for the Province of Manitoba, Canada. Average data per procedure using standard phantoms and standard ion chambers have been recorded since 1981. For example, chest air kerma (backscatter included) has decreased from 0.14 to 0.09 mGy. Confounding factors may negate the gains unless facility quality control programs are maintained. The data were obtained for a quality assurance and regulatory compliance program. Quoting such data for risk evaluation purposes lacks rigor hence a compartment model for organ apportioning, using organ absorbed doses and weighting factors, has been applied to determine effective dose per procedure. The effective doses for the standard procedures are presented, including the value of 0.027 mSv (1999) calculated for the effective dose in PA chest imaging.

1. INTRODUCTION

The Canadian province of Manitoba lies in mid continent with a population of 1.2 million persons. Health care facilities are distributed throughout the province with tertiary care concentrated in the provincial capital of Winnipeg. Radiation Protection Services is mandated by the Province to provide x-ray regulatory services for the health care facilities. An inspectorate group operating from the Medical Physics Department of CancerCare Manitoba surveys medical x-ray facilities annually. A compliance review is conducted during each survey and guidance is provided (and demonstrated) for changes in techniques that will maintain film density and image quality as well as controlling patient dose.

Legislation does not specify dose limits for entrance skin exposures in specified procedures. Rather the province-wide averages of the previous year's surveys are used to benchmark the entrance skin exposures for the current year's surveys. Entrance skin exposures are measured with selected phantoms in place, the thickness of the phantom being varied according to the procedure in order to simulate the patient. The year-by-year entrance skin exposure data for standard procedures have been tabulated to assess the trends. These data are reported here.

While entrance skin exposure data are an appropriate quality control tool, the data are erroneously used as the measure of patient dose. To address this concern, a means of calculating the effective dose has been implemented. The average effective doses for the standard procedures tested in the compliance program have been determined for the 1999 data.

2. METHODOLOGY

In performing the compliance tests, x-ray machines were set up in an identical manner to the technique used by the facility's technologists. The tube was set at a height of 100 cm (focal spot to film), the appropriate phantom was positioned as if it was the patient and imaging parameters (tube voltage, current and time) were obtained from the technologist. Phantom thickness was constant

for a specific procedure but varied according to the procedure (see Table I). Entrance skin exposure data were consistently measured with a 6 cc ion chamber (Radcal Corporation) and an MDH meter (1015 and 1515). The ion chamber was inserted in a machined receptacle at the top of the phantom block. Phantoms of various thickness were constructed from pressed wood having a specific gravity of 1.00.

Entrance skin exposure data were collected with the instrumentation in milliroentgen (mR) and were subsequently converted to air kerma in milligray (mGy): 1.00 mR = 0.00873 mGy.

3. RESULTS

Entrance skin exposure data are reported as air kerma for the 1999 survey year in Table I for the standard procedures measured in our program. Air kerma data include backscatter from the phantom. Data are also provided for tube voltage and phantom thickness and average film density, according to the procedure. Film speed is "400" throughout the provincial system.

Table I. Average air kerma data for standard procedures in Manitoba, 1999. Data shown are from x-ray machines with manual timing, anti-scatter grids and were obtained with phantom thickness as shown for the procedures. Tube voltages are nominal averages.

Imaging Procedure	X-Ray Tube Voltage (kVp)	Phantom Thickness (cm)	Average Air Kerma (mGy)	Average Film Optical Density
PA Chest	110	10	0.091 +/-.03	1.6
AP Abdomen	85	18	1.36 +/-.47	1.6
AP Cervical Spine	70	13	0.41 +/-.17	1.4
AP Thoracic Spine	75	18	1.15 +/-.42	1.3
AP Lumbar Spine	85	23	2.47 +/-.95	1.2
Lateral Skull	80	15	0.52 +/-.14	1.2

4. DISCUSSION

The regular program of compliance inspection and the added activity of interacting with x-ray technologists to assess the techniques and the consequent dose has resulted in the gradual decline in average air kerma and hence in patient doses. The introduction of 400-speed film has assisted in this reduction process. Nevertheless, confounding factors may be a potential source of further dose reduction on the one hand and may threaten the trend on the other. These confounding factors include:

(a) Reduced attention to quality control by the technologists may fail to observe changes in x-ray unit calibration or phototimer tracking.

(b) Cost-driven film changes and/or chemistry changes without testing.

(c) Radiologists reading different film densities from different facilities without feedback; different radiologists preferring films of different densities from the same facility.

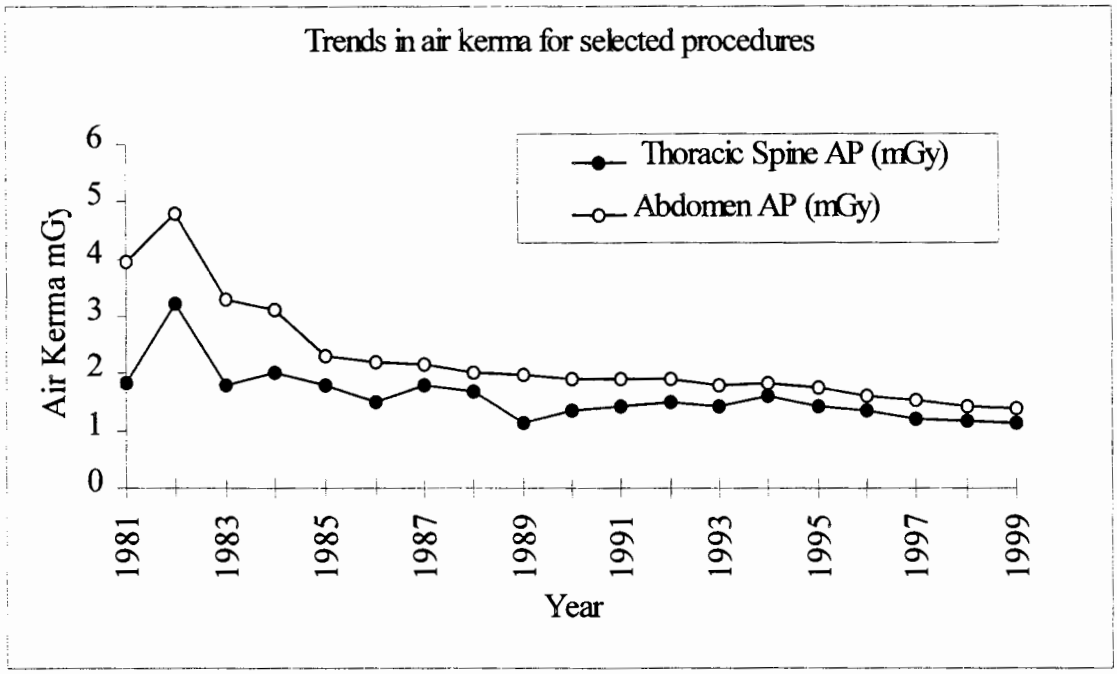
(d) Failure to track repeat and reject analyses and evaluate factors contributing to non-productive films.

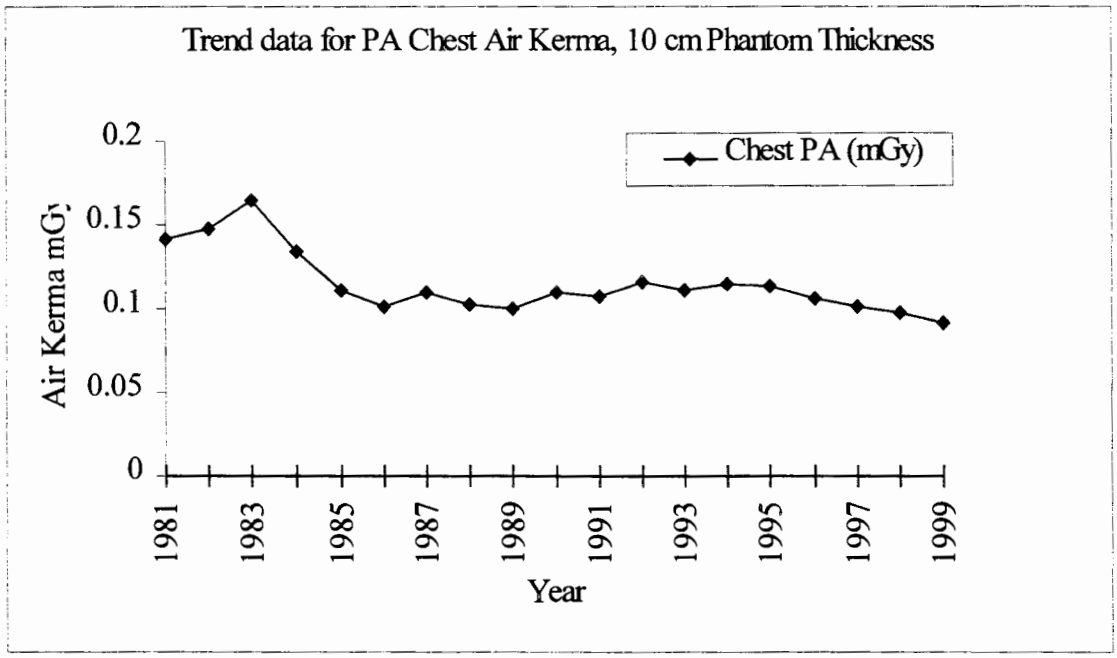
The confounding factors will be addressed through communication among radiologists and technologists and through adherence to the facility's quality control program.

Data include backscatter from the phantom.

Figure 2. Air Kerma trends in the period 1981 - 1999, inclusive, for PA Chest procedures with 10 cm phantom. Data include backscatter from the phantom.

Figure 1. Air Kerma trends in the period 1981 - 1999, inclusive, for selected procedures.





5. EFFECTIVE DOSE DETERMINATION

We used a compartment model derived from a Health Physics Society standard (1) to calculate effective dose from the standard procedures in our compliance program. Tissue weighting factors in Reference 1 were converted to those of ICRP 60 (2) and the "remainder" organs were adjusted. Body compartments were defined for the major procedures: head and neck, thorax, abdomen and extremities. The models for the first three compartments were applied to convert entrance skin exposure (air kerma) data to effective doses (see Table II). The application of this method was as follows:

- account for backscatter (taken to be 30% for this application);
- convert exposure data to air kerma "free in air" in SI units;
- determine the absorbed dose at depth for each critical organ in the respective compartment using the orientation-specific information in Reference 3 (assuming average photon energy equals 50% of kVp);
- apportion the organ masses to the imaging field of view as necessary and calculate the resultant tissue weighting factor for the organ in the compartment;
- the radiation weighting factor was unity; multiply the resultant tissue weighting factor by the absorbed dose to the organ (tissue) to obtain the organ effective dose;
- sum the effective organ doses for the diagnostic image to determine effective dose.

Table II. Effective doses for standard procedures using the compartment model.

Imaging Procedure	Imaging Compartment	Ave. Photon Energy (keV)	Air Kerma 1999 (mGy)	Effective Dose (mSv)
PA Chest	Thorax	55	0.091 +/-.03	0.027
AP Abdomen	Abdomen	42.5	1.36 +/-.47	0.525
AP Cervical Spine	Head and Neck	35	0.41 +/-.17	0.023
AP Thoracic Spine	Thorax	37.5	1.15 +/-.42	0.217
AP Lumbar Spine	Abdomen	42.5	2.47 +/-.95	0.953
LAT Skull	Head and Neck	40	0.52 +/-.14	0.018

6. CONCLUSION

Compliance surveys of diagnostic x-ray facilities indicate a downward trend in entrance skin exposures for standard imaging procedures. The trend requires vigilance and maintenance of quality control activities to avoid negating the gains. The data were converted to effective doses using a compartment model. While approximations exist in the effective dose calculations, the results are useful indicators of the potential risks from imaging.

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Estimate of induced activity in the head of High-energy medical linac

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Abstract:- When the operation of medical linear accelerator exceeds 10 MV,the staff workers are exposed to undesirable dose due to induced activity from radio-nuclides produced mainly in the accelerator head. Measurements carried out to estimate the radio-nuclides. As a result of the measurement the radio-nuclides Al^{28}, Cu^{62}, W^{187}, Ni^{57}, Fe^{59}, Co^{58} ($T_{1/2}$ = 2.3 min, 9.3 min, 24 h, 36 h, 45 days and 61 days respectively) are dominated, the activity will accumulated depending on the work load (patient number) and therefore the technician will be exposed to radiation every time they enter the treatment room.

Introduction:- Most teletherapy machine carried out now days using high-energy X-rays and electrons from linear electron accelerators, when the photon energy exceeds the binding energy of the accelerator construction materials, and other accessories around accelerator, which is approximately from 8-10 Mev, radioactive material can be produced due to photo-nuclear and neutron capture reactions depending on hoton energy and irradiated material, a number of radio-nuclides produced in accelerator head (Ahlgren and Olsson, 1988), and other accessories intercept the radiation found in the treatment room, induced activity may contribute in increasing the radiation dose to the technicians and the maintenance engineers. The most part of the accelerator which is exposed to the highest photon flounce rate such as he target, target holder, flattening filters and the collimators are the main source of induced activity, the bodies of technician are irradiated uniform mainly by gamma rays from induced activity, while the hands of technician irradiated by particles when they comes into direct contact with wedge filters, lead blocks and other accessories (A. Almen,all,1991).

Experimental methods: - This work carried out at Motol radiation oncology hospital in Prague 5, Czech Republic, where linear accelerator type Varian 2100C was installed and operating at 18Mev photons, to measure radio-nuclide gamma spectrometry are necessary, a high-purity germanium detector was connected to a portable gamma- ray spectrometer " the Dart" its used with maestro for window and gamma-vision program, and then moved inside treatment room to record the induced activity spectrum, the setup of the experiment as follow, high-purity germanium(Ge) detector shielded to avoid the scatter radiation was left at the isocenter of the beam, looking toward the target, maximum field size (40 * 40 cm) was open at normal treatment distance, a total maximum absorbed dose (50 Gy) of 25 patient was decided to know the effect of accumulated dose into increase the activity of radio-nuclide (2 Gy for a patient), the machine was on for about 25 min., the spectrum measurement taken not latter than about 8 min., the time necessary to move the instrument inside the treatment room after the accelerator was off. The measurement time interval divided as 1 min., 5 min., 10 min., 15 min., 30 min., and after every 1 h.

for about 16 h. from off the accelerator, the interval time was divided to cover the short and long half-lives of radio-nuclide

Results and discussion:- Using maestro with window program, the analysis was done, many radio-nuclides are know, most interest given to those long half-lives, the accumulated dose given increases the activity of long half- lives radio-nuclide, which are the source of undesirable radiation. Spectrum of gamma ray induced activity is shown in fig. 1,2, table 1 shows the radio-nuclides, there half-lives, and identified energies.

Table 1 induced radionuclides in the accelerator head their half- life and identify energies.

Radio-nuclides	Half-lives	Identify Energies (Kev)
Na^{24}	15 h	1369, 2754
Al^{28}	2.2 min	1779
Mn^{54}	302 d	835
Mn^{56}	2.6 h	847, 1811, 2113
Ni^{57}	36 h	1378, 1920
Fe^{53}	8.51 min	378
Fe^{59}	45.6 d	1099, 1292
Co^{58}	71 d	811
Cu^{64}	128 h	1346
annihilation (Cu^{62})	9.7 min	511
Br^{82}	35.3 h	554, 776, 828, 1044, 1318
Sb^{122}	2,7 d	564, 693
W^{187}	24 h	480, 618, 625, 686
Eu ^{152}	9,3 h	122.5, 1092, 1300
Sb^{124}	60.2 d	603

The gamma spectrum is dominated by the peak energy 511 Kev, which is annihilation radiation peak from Cu^{62}, and probably produced by the reaction Cu^{63} (γ, n) Cu^{62}, while the capper is use in the target holder. Al ^{28} ($T_{1/2}$= 2.2 min.) produced by neutron capture in Al, the radio-nuclides W^{187}, Mn^{54}, Mn^{56}, Ni^{57}, Fe^{53}, are contribute significantly to the absorbed dose and can be produced by the reactions W ^{186} (n , γ) W^{187}, Mn^{55} (n , γ) Mn^{56} , Fe ^{54}(γ , n) Fe^{53} , Mn^{55} (γ , n) Mn^{54} , Ni^{58} (γ , n) Ni^{57} , (L. Ahlgren & L. E. Olsson, 1988).

Conclusion:- Induced activity in the accelerator head significantly contribute doses to the whole body and hands of the staff worker operating the accelerator, therefor a proper choice of construction

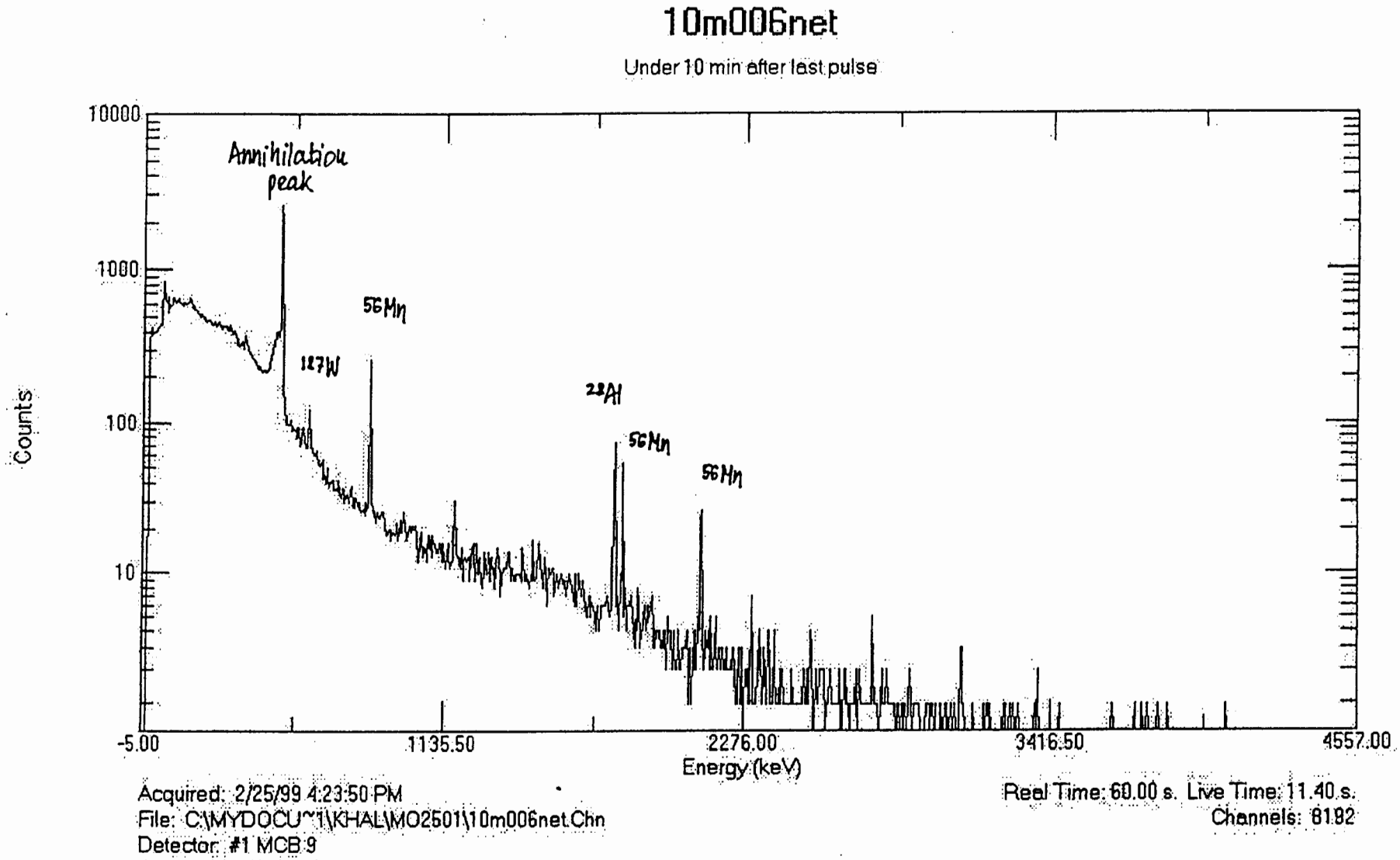

Fig. 1. Spectrum of gamma radiation emitted by radionuclides induced primarily in the accelerator head (detector at 63 cm from the collimator, 18 MV photons, 40 cm x 40 cm field size, total dose 5 0 Gy, measuring time interval 1 min, 7 min following the shut-up.

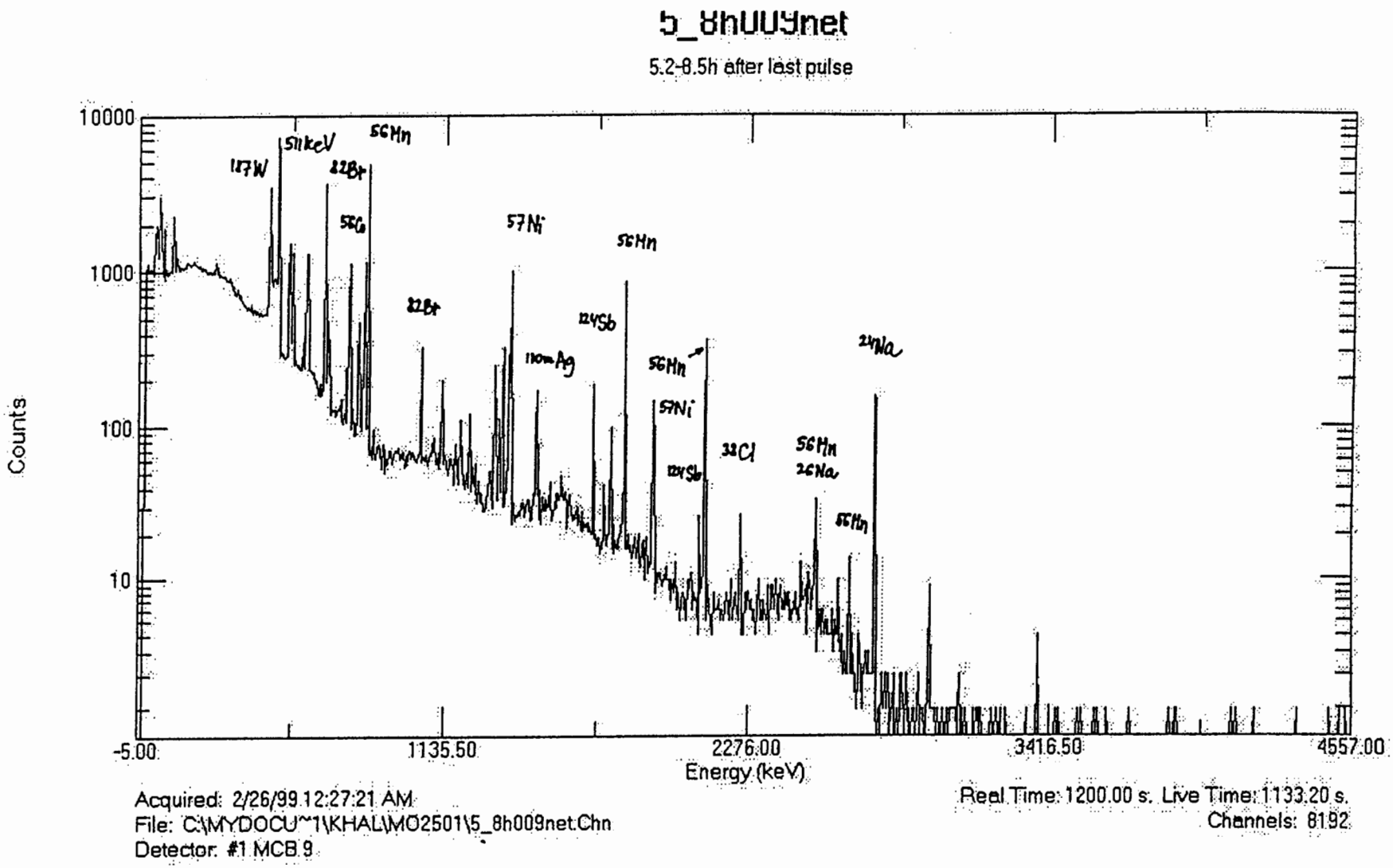

Fig. 2 Spectrum of gamma radiation emitted by radionuclides induced primarily in the accelerator head (detector at 63 cm from the collimator, 18 MV photons, 40 cm x 40 cm field size, total dose 5 0 Gy, measuring time interval 20 min, 8 h 30 min following the shut-up.

material could easily reduce the effect of induced activity, also the staff should save the time during preparing the patient for treatment, wear the lead apron can also save the staff, and measurement of dose rate is necessary from time to time, especially when there is need to make some maintenance inside the accelerator head.

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MEDICAL AND BIOLOGICAL APPLICATION OF RADIOPHARMACEUTICALS IN BANGLADESH.

Atia H.Jehan

Abstract

The application of nuclear medicine techniques in Bangladesh started as early as 1961 with limited investigations for liver and thyroid diseases .In the mid sixties under joint collaboration of Bangladesh Atomic Energy Commission and IAEA, plans for the peaceful use of atomic energy in the field of medical diagnosis and treatment were undertaken. IAEA assisted TC Projects helped the installation of sophisticated equipment and training of manpower. At present there are thirteen Nuclear Medicine Centers and an Institute of Nuclear Medicine which offers diagnostic and therapeutic services to the ailing humanity. Introduction and expansion and of RIA and IRMA facilities to most of the centers were an added advantage for assessment of thyroid disorders and their follow up. Static and Dynamic studies are routinely performed in all the centers along with therapeutic application of radioisotopes. The Nuclear safety and Radiation Control Division of BAEC, is vigilant in the implementation of safety regulatory procedures and reserves the right to deny license to practice. In the present context Nuclear medicine practice is considered as a safe, non invasive, beneficial and effective means of diagnosis and therapy with minimum radiation hazard.

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MEDICAL AND BIOLOGICAL APPLICATION OF RADIOPHARMACEUTICALS IN BANGLADESH.

Nuclear Medicine is globally practiced as a safe, non-invasive and effective mode in the diagnosis and treatment of human diseases. Radionuclide imaging is based in the detection of spatial and temporal distribution of an administered radiopharmaceutical into the body. A Radiopharmaceutical is a compound of a radionuclide and an organ specific pharmaceutical.
In Bangladesh only generator produced isotopes are available as there is no cyclotron and of these 95% are used for diagnostic purposes , while 5% for therapeutic treatment.. Radiolabelling procedures are carried out in the hot labs of the individual centers. The common isotopes,radiopharmaceuticals and their applications in Bangladesh are shown in Table 1 .

RADIOPHARMACEUTICAL	STUDY
^{99m}Tc HDP/MDP	Bone Scintigraphy .
^{99m}Tc DTPA	Renogram , GFR, , Brain .
^{99m}Tc DMSA	Renal Scan .
^{99m}Tc HMPAO	Functional Imaging of Brain.
^{99m}Tc TETROFOSMIN(MIBI)	Cardiac Perfusion , STRESS , REST, Scintimammography.
^{99m}Tc HIDA	Hepatobiliary Scan .
^{99m}Tc SULPHUR COLLOID	Liver , Spleen , GIT (Gastric Emptying).
^{99m}Tc MAA	Lung perfusion.
^{99m}Tc PERTECHNETATE	Thyroid , Testicular Scan, Salivary Gland , Parathyroid.
^{99m}Tc PYROPHOSPHATE	RBC Labeling , gastric blood loss.
^{131}I Na-I	Thyroid Uptake , Thyroid Scan , Whole body scan for Ca Thyroid.
^{201}Tl CHLORIDE	Myocardial Stress & Rest , Parathyroid , Whole body scan for Ca Thyroid.
^{51}Cr RBC LABELING	RBC Volume & Survival .

Table 1 : Diagnostic Application of Radiopharmaceuticals

Therapeutic uses are limited to the treatment of Ca. Thyroid, and Thyrotoxicosis with ^{131}I and the doses are given either in the form of capsule or liquid. Besides this ^{90}Sr for Pterygium ^{32}P for Polycythemia are also used for therapeutic purposes (Table 2).

ISOTOPE	SOURCE	THERAPY
^{131}I	CAPSULE LIQUID	Ca. Thyroid Thyrotoxicosis .
^{32}P		Polycythemia .
^{90}Sr		Pterygium

Table : 2 Therapeutic Application of Radiopharmaceuticals

There are sixteen Nuclear medicine centers in the country of which 14 are under the Bangladesh Atomic Energy Commission (BAEC) and two are privately run. SPECT facilities are available in seven centers .

Man made exposure to radiation[1] is 14 % of which 4 % is from nuclear medicine installations, 10 % from diagnostic X – rays and < 1 % from other sources while 86 % comes from natural sources. Percentage of Radiation Exposures are shown in Fig. 1

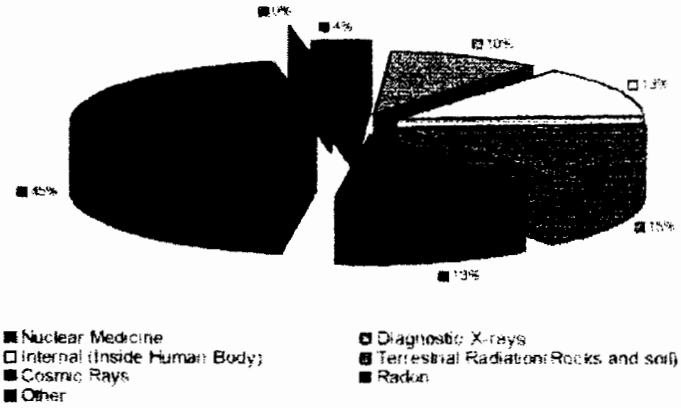

Fig. 1 : Percentage of Radiation Exposure

At the centres, in the process of generator handling, dose preparation , dispensing and imaging the nuclear medicine personnel are directly or indirectly exposed to ionizing radiation.Occupational workers , patients , attendants and the general public carry associated risks and detriments of special type and nature. Uncontrolled use increases stochastic effects on human as well as the environment. Time of exposure, distance and shielding plays an important role as a protective device. The B.A.E.C has bestowed legal responsibility to The Nuclear Safety and Radiation Control Division(NSRCD) for issuing licence to practice Nuclear Medicine in Bangladesh under NSRC Act No. 21 of 1993(Government of Bangladesh) . The total number of licence applications received from October 1997 to June 2000 were 134 and the number of lincences issued were 104 (**Fig. 2.**)

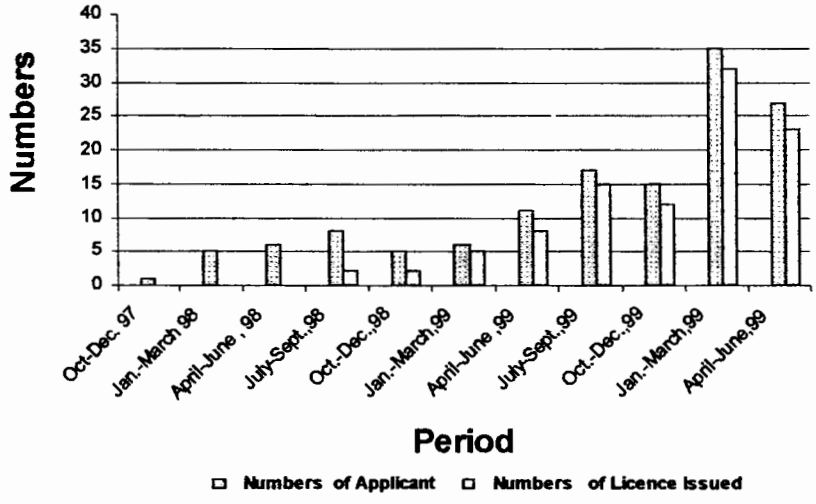

Fig . 2 : Status of Licence Applications received and Issued .

Misuse and uncontrolled sources may cause burn injury while long term or stochastic detriments may cause cellular mutations or genetic disorder. There is no threshold on the

amount of exposure required for causing these disorders in the human body. Wearing gloves and film badge monitoring , act as a filter against radiation hazard.

An IAEA sponsored workshop on **Radiation Protection and Quality Assurance** was held recently in the capital with participants from nuclear medicine , radiology and radiotherapy department. Radiation protection and the importance of quality assurance were highlighted in the workshop.

The society needs assurance that safety to the occupational workers and protection of the environment shall not be compromised. Implementation of quality assurance program is mandatory for every licence holder. The applicants are advised to prepare quality assurance program in their respective centers so that maintenance of nuclear medicine equipment like gamma camera are systemic and satisfactory. Protective gloves , film badge, lead syringe , lead glass shielding , fume hood,safe disposal of radioactive substances , building design , construction, consumption and operation greatly reduces the risk of radiation exposure. Apart from this, quality assurance is specially important for composite image performance. Poor quality image production may lead to false positive results. Therapeutic patients given ^{131}I are specially vulnerable of causing radiation hazard to the general public and the environment. In spite of all precautions these patients fail to realize the importance and ignore all the advise given to them. Indiscriminate disposal of excreta and saliva cause environmental pollution. The rate of Iodine excretion is shown in fig.3.

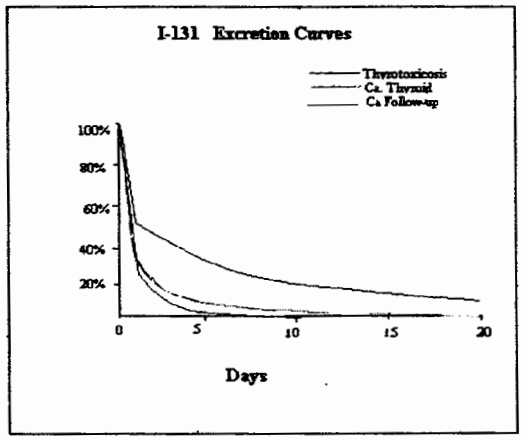

Fig. 3 : I-131 excretions curves in percentages of administered activities

CONCLUSION

The risk of radiation exposure associated with nuclear medicine practice is comparatively is lower than that of radiotherapy and radiological investigations. The possibility of contamination and isotope spill is high but limited within the dispensing room and laboratories. The radiation hazard to the general public and the environment must not outweigh the benefit to the patient. The practice demand attention of the facility management and regulators. The quality of radioisotope , quantity , supply and storage plays an important role in prevention of radiation hazard to the occupational workers and patients. Using standardized equipment, trained personnel and proper radiopharmaceuticals, nuclear medicine practice may be considered as one of the safest non invasive and accurate method in the diagnosis and treatment of medical disorder.

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INTERNATIONAL CONFERENCE ON THE RADIOLOGICAL PROTECTION OF PATIENTS

in

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Radiological Protection of The Foetus
(In Pregnant Patients)

Physics is a fundamental science. The developments of the various parts of physics have a profound influence on all the other science.

Recently physical medicine plays important roles in the medical fields.

The ionizing radiations such as X-rays and the radiation from radioactive materials are serving for diagnosis and treatment of harmful diseases like cancers and tumors.

Ionizing radiations also have some risks and biological damage specially on the foetus during the Pregnancy.

Fundamentally, the biological affects of the ionizing radiations are due to the interactions of the radiations with the atoms and molecules of the body, resulting in ionization of excitation of atoms or disruption of molecules within the organism.

The biological affects of ionizing radiations are:

1. Somatic Affects;
2. Genetic Affects.

Ionizing radiations applied to the back or abdomen would reach the pregnant' s uterus.

According to the information of the recent printed books and studies in radiological services of Kabul hospitals we can conclude that:

1- Ionizing radiations cause the fetus that they will have birth-defects or genetic abnormality.

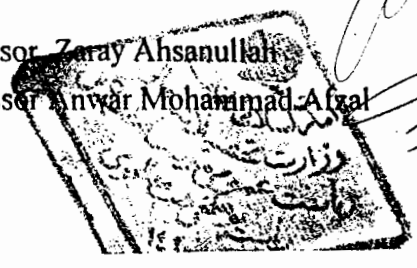
2- Ionizing radiations applied to the back, abdomen and uterus of the pregnant patient is from contraindications.

3- Pregnant patient must avoid X-rays unless essential and approved by a physician.

4- Prevention of the patients from fertilization is the best way of protection.

By : Ibrahimi Khan Mohammad.

Recommended by : Professor Zaray Ahsanullah
Professor Anwar Mohammad Afzal



A PROJECT: "RADIOLOGICAL PROTECTION IN RADIOLOGY". IAEA - UNIVERSIDAD CENTRAL DE VENEZUELA

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ABSTRACT

For several years a reference center of the UCV has been working in the project VEN/9/007 on dose reduction in diagnostic radiology sponsored by the IAEA.

The dose and quality image was evaluated for different types of radiological study (conventional radiology, CT, mammography, interventional radiology) in different facilities at Caracas and others regions of the Venezuela. For assess and reduction dose were used dosimeters TL, the recommendations given by CEC documents on diagnostic quality criteria, a quality control program and the associated instrumentation. Works in radiological protection of patients and staff have been developed, for example: Pilot study by using TLD in personnel radiation monitoring. Comparative study between high and low Kvp in chest. Evaluation and dose reduction in chest pediatric. Reduction of radiation dose in studies of billiards via. Quality Image and reduction of the dose in studies of colon by enema. Radiation dose of staff in fluoroscopy procedures. Evaluation and dose reduction in dental radiography in public Institutions. A mammography accreditation program for Venezuela, applied to public hospitals.

INTRODUCCIÓN

En el área de medicina hay un importante porcentaje de enfermedades diagnosticadas con el uso los Rayos X. Por lo tanto, cualquier país que aspire mejorar los programas de cuidados de salud de su población debe garantizar su uso adecuado y seguro. En tal sentido, el Organismo Internacional de Energía Atómica(OIEA) ha publicado las Normas Básicas para la protección contra la radiación ionizante, donde se dedica un apéndice para la exposición médica y particularmente a la protección radiológica del paciente [1]

Pero en el área de radiodiagnóstico, además de la protección radiológica del paciente, es fundamental la calidad de la imagen obtenida, para garantizar un diagnóstico adecuado. La Comisión de las Comunidades Europeas(CEC) ha elaborado un documento sobre criterios de calidad para diferentes estudios radiológicos [2]

Pero una buena calidad de imagen con dosis bajas al paciente depende de diversos factores, entre ellos, el funcionamiento de la unidad, las condiciones de las instalaciones y de los equipos; los insumos; las técnicas para la obtención de la imagen; la calidad del servicio de mantenimiento.

En esta dirección, a comienzo de los años noventa, el OIEA patrocinó un estudio piloto en algunos países, para reducir dosis en pacientes y al mismo tiempo evaluar la calidad de imagen obtenida en diferentes tipos de estudios radiológicos[3]

En la misma dirección de ese estudio, el centro de Física Médica y Dosimetría (CFMD) de la Universidad Central de Venezuela(UCV) ha desarrollado el proyecto VEN 9/007 "Protección Radiológica en Radiología", subvencionado por el OIEA. En el presente trabajo se muestran algunos resultados relacionados con la medición y reducción de dosis en pacientes y el monitoreo de la calidad de la imagen.

MATERIALES Y METODOS

Las evaluaciones se realizaron en los servicios radiológicos del Hospital Universitario de Caracas (HUC) y la Facultad de Odontología de la UCV, y en servicios de radiología de otras instituciones médica u odontológica de Caracas y del interior del país. Para ello se tomó como patrón de trabajo, la metodología desarrollada en el estudio piloto del OIEA y otras experiencias en esta área [4][5]

El procedimiento se realizó en tres fases. La primera se utilizó para obtener información básica sobre el servicio de radiología por medio de un cuestionario. En este se indagó sobre la calificación del personal, el equipamiento, insumos, técnicas radiográficas, y las prácticas de control de calidad y mantenimiento.

En la segunda, por una parte, se efectuó una evaluación física de la cadena para la toma radiográfica, para ello se siguió el protocolo español de control de calidad en radiodiagnóstico[6] Por otra, se tomaron las radiografías de pacientes (o de maniquíes) y se midió la dosis de entrada, sin modificar ningún parámetro de la cadena. Para la evaluación de la calidad de la imagen clínica se siguieron los criterios propuesto por la CEC y para medir la dosis de entrada se utilizaron dosímetros termoluminiscentes (TLD-100)

En la tercera fase, previa a la toma radiográfica, se modifica(n) el (o los) parámetro(s) de la cadena que pueda(n) - de acuerdo a los resultados obtenidos en la segunda fase - estar influyendo en un aumento de la dosis de radiación que está recibiendo el paciente (o el maniquí) En estas nuevas condiciones se mide la dosis y se evalúa la imagen clínica obtenida.

RESULTADOS

Los trabajos se desarrollaron con la colaboración de estudiantes de pregrado u postgrado de la UCV que hicieron su tesis en el CFMD, o profesores que realizaron su trabajo de investigación en el Centro. A continuación se presentan – en forma resumida- algunos de los 53 trabajos realizados entre 1995 y 1999.

I. Evaluación y reducción de los rangos exposición en radiología odontológica en el área metropolitana de Caracas[7]

En radiología odontológica, probablemente una de las causas por la que los pacientes están expuesto a recibir mayor dosis, se debe a que se aumenta el tiempo de exposición al paciente en función de disminuir el tiempo de revelado de la película y no siguen las especificaciones para el revelado de la película dadas por el fabricante. Esto, además, puede influir en la calidad de la imagen obtenida.

Para evaluar esta situación la investigación en servicios odontológicos públicos de Caracas se midió la dosis de entrada y se evalúo la calidad de imagen con un maniquí odontológico. Se utilizaron, para ello, los parámetros de exposición y el proceso de revelado que usa el servicio visitado habitualmente. Posteriormente, en una nueva visita, se evaluaron los mismos parámetros, pero siguiendo las condiciones de preparación de químicos y procesamiento recomendado para las películas por el fabricante, y la técnica de exposición ajustada a las nuevas condiciones.

Resultados: Disminución - en algunos caso - hasta de un 80 % de la dosis de radiación medida en los consultorios visitados y una mejora significativa de la calidad de imagen.

II. En los cinco trabajos citados se evaluó la calidad de imagen y la dosis para técnicas de bajo y alto Kvp.

1. Estudio comparativo entre el alto y bajo Kvp en patología del mediastino en el servicio de Cardiología del HUC [8]

2. Calidad de la imagen y dosis en tórax en el servicio de radiología general del HUC [9]

3. Evaluación y reducción de dosis en tórax pediátrico en el Hospital Julio Criollo Rivas de Caracas [10]

4. Determinación y disminución de la dosis a pacientes sometidos a estudios de vías biliares del servicio de Gastroenterología del HUC [11]

5. Reducción de dosis en radiografías de tórax del examen preventivo del Hospital Industrial de San Tome, Estado Anzoátegui [12]

Resultado. Con la técnica de alto Kvp se obtuvo adecuada calidad de la imagen y la disminución de la dosis recibida por el paciente

III. Calculo y reducción de la dosis en Estudios simples de tórax, columna lumbar, y pelvis en la Clínica Industrial CORPOVEN-Anaco-Anzoátegui. [13]

Parte de los estudios radiológicos realizados en tórax, columna y pelvis en esta clínica se utilizan con fines de contratación laborales. En este sentido, el trabajo de investigación, por una parte, evalúa el hecho de someter a las personas que solicitan empleo a una evaluación radiológica y por otra, para reducir la dosis de radiación, se cambio el tipo de películas y chasis convencionales por pantallas de tierras raras y películas adecuadas.

Resultados: Se logró disminuir la dosis y se mejora la calidad de la imagen. Asimismo se hizo una revisión de los archivos radiológicos de la clínica – para el caso de las radiografías de tórax - en lo que se refiere al valor de estos estudios para el caso de las personas que solicitan empleo, más del 90 % de las personas evaluadas presentaron una imagen de tórax normal.

IV. Elaboración de un programa de acreditación para unidades de mamografía en Venezuela y su aplicación a las unidades de hospitales públicos de Caracas [14]

En 1994 se realizó, en Venezuela, un primer trabajo en esta área, donde se evaluó la calidad de la imagen y la dosis de radiación en los mamógrafos de Caracas[15] Como continuación de ese trabajo, en el presente se elabora un programa de acreditación para unidades de mamografía en Venezuela. Asimismo, el programa de acreditación propuesto se utilizó para evaluar las unidades de mamografía de los hospitales públicos de Caracas.

Resultados: **Con relación a las características de funcionamiento y normativa que rigen el tipo de servicio médico asistencial**, no existe una normativa común, ni criterios ni parámetros de selección específicos. **Con relación a la evaluación de la calidad de la imagen del maniquí**, solo un centro está dentro de los límites de tolerancia para la prueba. **En cuanto a la calidad de la imagen clínica,** el 70 % de los centros no cumplieron criterios de colocación adecuada. **Con respecto a la exposición**, las fallas en la técnica de exposición estuvieron presentes en el 57% de las imágenes obtenidas. **La presencia de múltiples artefactos**, fue considerada como una fuente en la reducción de la calidad de la imagen. **Con relación a la medición de la dosis de entrada**, solo una de las unidades estuvo dentro de los límites de tolerancia permitidos.

V. Dosis al personal que labora en procedimientos radiológicos con fluoroscopia en el Hospital Universitario de Caracas [16]

En radiodiagnóstico, uno de los procedimientos donde el personal recibe mayor dosis de radiación es en los estudios angliográficos. En este trabajo se evalúan los procedimientos de protección radiológica seguidas y la dosis recibida por el personal. Se le mide la dosis con dosímetros TL a nivel del cristalino, tiroides, tórax, mamas, y gónadas.

Resultados: Se determinó que el médico intervensionista recibe una dosis alta cuando no se siguen procedimientos de protección radiológica.

CONCLUSIONES

Con el desarrollo del Proyecto VEN/9/007 se pone en práctica una metodología para el uso eficiente y seguro de las fuentes de radiación ionizantes en radiodiagnóstico. Sumado a esto, la incorporación de alumnos y profesores al proyecto, a través de la realización de tesis y otros trabajos de investigación, no solo da importantes aportes para el caso de Venezuela, sino que en su desarrollo están explícitos los conocimientos adquiridos por este personal y que pueden poner en práctica en su trabajo en los centros de atención médica donde laboran, lo cual contribuye a obtener imágenes de buena calidad y con dosis baja de radiación.

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IAEA-CN-85-34

HOW CHANGES IN A RADIOLOGIST'S TECHNIQUE CAN REDUCE PATIENT DOSE IN BARIUM ENEMA STUDIES

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Abstract

Changes in a radiologist's technique, especially utilising digital technology, can lead to substantial dose savings in barium enema examinations. Data will be provided showing a 20% saving with only minimal change in technique.

Introduction

Since the publication of ICRP60, there has been a considerable amount of work carried out by many to reduce the dose received by patients during common fluoroscopy procedures. This has included equipment improvements, optimisation of equipment, use of fast film/screen combinations, etc. Papers have been published showing large dose savings can be made by attention to equipment [1, 2], but also numbers of papers have been published which have commented that dose can vary considerably depending on the clinical technique [3-11]. These comments do not appear to have been noticed by the radiological community at large, but there are exceptions.[12,13] Many suggest that dose can be reduced by careful clinical radiological technique. This paper follows on from my presentation at IRPA10. [12]

Table 1. Dose results for Barium Enemas.

	Films	Scr.Time	DAP $Gycm^2$	Films	Scr. Time	DAP $Gycm^2$
Martin [1] (Range)	12.2 (11.8-12.5)	1.6 (1.5-2.2)	26.1 (11.9-37.6)	12.2 (12-12.4)	3.1 (2.5-3.7)	17.3 (8-26.6)
Hart [7]	10.1	2.9	20	10.7	3.8	16.6
Broadhead [8] (Range)	9.2 (0-30)	2.9 (0.7-38)	21.3 (0.2-1110)	9.7 (0-90)	2.8 (0.5-14)	11.7 (1-399)
Geleijns [9]	28	7.7	21.4	27	7.8	15.3
Warren-Forward [14] (Range)	6.8 (3-11)	2.4 (1.8-3.2)	29.2 (15-47)	8 (3-15)	2 (1.5-2.3)	25 (16-39)
Yakoumakis [2]	7.4	6.2	35			
Lampinen [15] (Range)	11.6 (3-21)	3.2 (1.4-11.9)	35.8 (8-140)			
Ruiz – Cruces[13]		3.8	56.9			
Vaño[16]			49			
Corbett[12] (Range)	12 (9-14)	1.8 (1-3.7)	23.8 (10.1-46.9)	12 (9-14)	3.2 (0.3-9.6)	23.8 (1.4-78)

Discussion.

Table 1 gives published results for barium enemas from authors from several countries, my results and personal observations from Professor Vaño, Spain.[16]

The introduction of Reference Dose Levels in the European Union has spawned a number of publications and conferences [17-20] to highlight their use. These have been well attended by medical physicists. Very few radiologists have attended or shown any interest so far. The purpose of Reference Doses or Levels is to instigate an investigation as to why any examination should give consistently high dose over a period of time. These levels have to be set either EU wide, Country wide or even just within a department. However it is quite clear from the tables that there is a considerable variation between doses in different countries, departments and even equipment. While the equipment variation is well known and has been addressed before, the variation in technique between individual radiologists has not been extensively investigated. I feel this is largely because of that jealously guarded 'right': clinical autonomy. This means that any radiologist feels he or she may use as much radiation as they feel like to get the required clinical information. Each radiologist has his or her own way of doing things. Some take more films, some use extensive screening, and some use video grab. None, or very few, use the same way. From the tables, it can clearly be seen that there must be a major philosophical difference between the way radiologists in the UK, as a whole, work and elsewhere. UK doses are low compared with many other countries. Ruiz-Cruces reports average doses of 56.9 $Gycm^2$, almost 5 times greater than doses from Hairmyres Hospital, described in Table 3. There is even a drive led by the UK National Radiological Protection Board (NRPB) for even lower doses, achievable doses.[21] It will be very difficult to measure the influence of this dose variation, as clinical outcome studies have not to my knowledge been published. Work has been done in Edinburgh, Scotland, on this, which is the subject of a further paper currently in preparation.

Table 2. Dose data from Stonehouse Hospital

Radiologist	Procedure	Films	Screening Time	Dose ($Gycm^2$)
A	Enema	8.7 (4-11)	4.5 (1.1-10.4)	55.1 (30.7-111.5)
B	Enema	8.5 (6-10)	2 (1.4-4.9)	30.1 (13.1-54.2)
C	Enema	11 (9-12)	1.4 (1-2.2)	30.8 (10.8-50)

I have mentioned that there can be differences in dose between individual radiologists using the same equipment. Table 2 shows some results by radiologists for an analogue unit in our department. Two radiologists have similar DAP results, though with varying screening times and film numbers. The other radiologist screens nearly three times as much and has doses almost double the Scottish Reference Dose Levels. ($32Gycm^2$). This was a radiologist of "the old school" who has now left our employ.

Table 3. Dose data from Hairmyres Hospital

Radiologist	Procedure	Screening Time	Dose ($Gycm^2$)
C - 1996	Enema	1.8	17.4
C – 1998	Enema	1.5	14.6
D – 1996	Enema	4.3	32.3

D – 1998	Enema	3.7	29.3
E – 1996	Enema	4	29.2
E – 1998	Enema	4.2	30.4
C - 2000	Enema	1.3	11.4

Some results of doses for enemas made at different years have been obtained following installation of a digital unit. While the doses remain within the Scottish Reference Dose Levels, 2 radiologists show a slight increase in mean dose and screening time with the passage of time, while Radiologist C shows no increase. This may reflect patient mix. The important aspect to note is that the dose levels remain well within the Scottish Reference Dose Levels. Consistently they are between half and a third of the doses reported in other countries.

However complacency is unacceptable. Recently I have introduced a new view into my routine for barium enema studies. This view, a prone shoot through of the rectum, carries a high dose. In order to reduce my dose overall, I now take the filing phase images as 'video grab', not as exposed images. I have found these to be acceptable for diagnostic purposes. This change, including introducing the new view, has led to a 20% reduction in the mean dose received by my patients: 14.6 $Gycm^2$ to 11.4 $Gycm^2$. There has also been a slight decrease in my screening time from 1.5 to 1.3 minutes. I am not yet happy to take more views by video grab, but I know others are working on this. It may well be that with even newer digital systems, we may be able to go as far as to obtain all views by video grab, with a major dose saving.

Conclusion

It remains unlikely that radiologists will willingly change their techniques to those that use less dose unless they can be shown that such techniques are just as good. This would require a massive re-education and training programme that may just not be cost effective, but perhaps I have shown by example that it is possible. However there remains a major difference between the doses from different countries that will have to be explained further. Analogue v. Digital technology is just not enough.

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RODRIGUEZ GOMEZ, Anabel

From: ORTIZ LOPEZ, Pedro
Sent: Tuesday, 10 October 2000 18:46
To: RODRIGUEZ GOMEZ, Anabel
Subject: FW: Paper for the upcoming meeting on radiation in medicine

Necesitaremos el full paper pero de momento pon el Abstract en el file, por favor
Gracias

Pedro Ortiz

— e-mail was sent requesting paper. 15.10.00

From: GONZALEZ, Abel Julio
Sent: Tuesday, October 10, 2000 2:50 PM
To: ORTIZ LOPEZ, Pedro
Cc: 'Charles Hardin'; SCHMID, Hildegard
Subject: RE: Paper for the upcoming meeting on radiation in medicine

As requested

-----Original Message-----
From: Charles Hardin [mailto:chardin@crcpd.org]
Sent: Tuesday, October 10, 2000 2:29 AM
To: GONZALEZ, Abel Julio
Subject: Paper for the upcoming meeting on radiation in medicine

Attached is an abstract for presentation at the upcoming meeting in Spain on radiation in medicine. I have tried to send it to Pedro but keep getting undelivered. Please forward my abstract to Pedro, and if the paper is acceptable, I would appreciate an invitation to speak at the meeting prior to our next board meeting, which is Nov. 1st. Our board will consider on who the CRCPD will send to the meeting. Please advise if you need a hard copy, or is this email attachment adequate? In the event that you cannot open the attachment, which is in WordPerfect format, I have also made the abstract a part of this message.

ABSTRACT

The infrastructure for the regulation of radiation sources in the United States includes both state and federal levels of government. In some areas, even local governments play an important role in the regulatory process. The regulation of the use of radioactive materials in nuclear medicine is by the states where such states have an agreement with the U.S. Nuclear Regulatory Commission (NRC). Under this federal/state agreement, the NRC has transferred certain regulatory authority to these states for the licensing, inspection and enforcement of regulations for nuclear medicine activities. For those states that do not have an agreement, the NRC retains authority and responsibility for the regulation of nuclear medicine activities. Of the fifty states, thirty-two have such an agreement with the NRC.

For x-ray machines used in the healing arts field, the states have the total responsibility for regulating the use of such equipment. The Food and Drug Administration (FDA) has responsibility for the manufacture of such equipment, which must meet certain performance standards adopted by the FDA, but the states regulate the use of such approved equipment.

This paper will discuss this regulatory infrastructure in the United States. Emphasis will be placed on how regulations are developed, including the basis for regulatory decisions, the inspection process both at the federal and state level, and the various enforcement actions that can be taken by both the federal and state governments to ensure compliance with adopted regulations.

This paper will also address how these regulatory agencies benefit from standards and recommendations set forth by organizations such as the National Council on Radiation Protection and Measurements, the American National Standards Institute, the International Council on Radiation

Protection, and other national and international organizations. In particular, this paper will address how states benefit from recommendations of the Conference of Radiation Control Program Directors.

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DOSE DISTRIBUTION OVER THE RADIATION FIELD AND ORGANS OF THE BODY DURING RADIOTHERAPY PROCEDURES

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ABSTRACT

Beam profile of the ^{60}Co teletherapy unit for 10 cm X 10 cm along central axis was measured to study the symmetry of the gamma beam and found that the average dose was 98.44±1.40 mGy. Output dose versus field size was also measured and values were found reasonable. Dose prescription to delivery was measured by placing TLD onto the treatment field for lung and cervix cancer patient which was found to be 39.16±2.98 Gy and 50.48± 3.68 Gy respectively which are within 2 % and 0.17 % of the prescribed dose as 40.00 and 50.40 Gy respectively, reveals good agreement with the treatment planning. Six typical types of patients both male and female with cancers in lung, larynx, breast, cervix, oesophagus and brain treated with ^{60}Co teletherapy were particularly considered for dose assessment at different critical organs of interest. It was observed that the doses to the lens of eye with a maximum value of 460.35+78.87 mGy for a larynx cancer patient to a minimum value of 30.80+4.00 mGy of a cervix cancer patient. Doses to the gonad vary with a maximum value of 3810.80+389.76 mGy for a cervix cancer patient to a minimum value of 8.20+1.00 mGy for a brain cancer patient.

INTRODUCTION

Ionizing radiation is being used worldwide as essential tools for protecting and improving human health. It is estimated that medical applications of radiation account for about 95% of the exposure to radiation from man-made sources (as reported by UNSEAR). The objective of radiotherapy is to ensure that the target tissue is given the prescribed dose keeping minimum dose to surrounding health tissue. The success or failure of radiotherapy depends upon the accuracy of radiation dose to tumour volume. Radiation dose requires dose optimization to the tumour, as it should not vary within 5% of the prescribed dose. The significant variation in dose, dose distribution or dose fractionation, serious consequences can arise. Applying the well-

designed quality assurance programme are necessary in order to ensure the protection of patients. About 60% of all cancer patients will require radiation therapy during some phases of their cancer care. Dose uniformity within the tumour volume and sparing of risk organs are important considerations in judging a treatment plan. The undue radiation to the organs may be one of the reasons for secondary metastasis for long-lived survivors [1].

In this paper, some parameters of quality assurance programme were carried out and radiation dose to the critical organs during the radiotherapy procedures was measured by thermoluminescent dosimeter (TLD). An ALCYON II cobalt-60 teletherapy unit (CGR, MeV, France) of activity 223.6 TBq (09 June 1994) has been installed at the Delta Medical Centre Limited, Dhaka, Bangladesh in August 1994.

Material and Methods

A phantom made of plexiglass having the dimension of 30 cm X 30 cm X 30 cm have been fabricated by using 0.5 cm thick plexiglass sheet. Beam profile was measured along the axis of the field size 10 cm x cm. Field size, SSD, isocentre were checked before each measurement. Out put dose for different field size were also studied. Lithium Fluoride crystal in the form of chips (TLD-100) were used as TL dosimeters in this study and those were made grouping and ready for experiment by using TLDSHELL software.

Results and Discussion

Dose distribution i.e. beam profile of 10 cm X 10 cm field size were measured along the axis of the field at dmax and dose data are presented in the Table 1 with the value of 98.44 ± 1.40 mGy. Dose dependence on field size was measured for 5 X 5 ... and shown in Table 2. An equation obtained by using Excel 97 and the equation is $Y = 27.377\ln(X) + 100.58$ with $R^2 = 0.8452$.

Table 1: Beam Profile along the axis of radiation filed of 10 cm X 10 cm.

Distance in cm	Dose (mGy)
-10	1.78
-8	3.38
-6	39.59
-4	96.41
-2	99.52
0	99.19
2	98.63

4	68.35
6	37.82
8	3.17
10	1.11

Table 2: Dose variation with field size

Field Size (cm X cm)	Dose (mGy)
5 X 5	151.57±19.91
10 X 10	154.77±7.61
15 X 15	168.30±8.131
20 X 20	183.63±10.98
25 X 25	196.00±4.44

Organ dose was determined under typical treatment procedures and the dose data are shown in Table 3. It is observed from the Table 3 that the prescribed dose for lung and cervix cancer were 40.00 Gy and 50.40 Gy respectively and the dose measured onto the treatment field area were 39.16±2.98 Gy and 50.48± 3.68 Gy respectively which are within 2 % and 0.17 % of the prescribed dose. These indicate that the study reveals an excellent agreement with the "dose prescription to delivery".

For laryngeal cancer treatment, the lens of eye receives 0.46±0.079 Gy which is comparable with the dose received by the lens of eye are 639+8, 568+8 and 533+7 mGy as reported by F. K. Miah et.al. [2] For the typical brain cancer radiotherapy, gonadal dose found to be 8.2+1.0 mGy considering 45 Gy tumour dose to the brain. M. Mazonakis et. al, [3] determined the conceptus dose during radiotherapy using anthropomorphic phantom delivering 65 Gy to the tumour without using shielding equipment to the conceptus region and dose found to be 17.0, 21.7 and 28.3 mGy at 4, 12, 24 weeks of gestation respectively. It is, therefore, essential to put necessary shielding to the critical organs, especially gonad during radiotherapy to reduce the potential risk due to the scattered photon.

Table 3 : Dose distribution (Gy) over various organs of the patients during typical treatment procedures with the ^{60}Co teletherapy.

Cancer site & Sex	Lens of Eye	Neck	Chest	Abdomen	Right Arm	Left Arm	Right Leg	Left Leg	Gonad
Lung (Male)	0.14 ± 0.03	1.04 ± 0.13	39.16 ± 2.98	0.13 ± 0.004	0.20 ± 0.014	0.16 ± 0.03	0.005 ± 0.0005	0.005 ± 0.0002	0.022 ± 0.002
Larynx (Male)	0.46 ± 0.08	3.99 ± 1.28	0.19 ± 0.013	0.043 ± 0.003	0.074 ± 0.005	0.083 ± 0.012	0.011 ± 0.0007	0.012 ± 0.0007	0.023 ± 0.002
Breast (Female)	0.21 ± 0.03	1.99 ± 0.32	6.30 ± 1.70	0.28 ± 0.05	0.15 ± 0.021	0.61 ± 0.02	0.02 ± 0.002	0.016 ± 0.001	0.10 ± 0.008
Cervix (Female)	0.031 ± 0.004	0.088 ± 0.006	0.26 ± 0.024	50.48 ± 3.68	0.44 ± 0.03	0.44 ± 0.041	0.10 ± 0.004	0.15 ± 0.018	3.82 ± 0.39
Oesophagus (Female)	0.02 ± 0.035	2.55 ± 0.72	35.54 ± 2.15	0.52 ± 0.027	0.27 ± 0.035	0.15 ± 0.014	0.007 ± 0.0004	0.008 ± 0.0008	0.009 ± 0.0008
Brain (Male)	0.44 ± 0.06	0.23 ± 0.021	0.04 ± 0.004	0.02 ± 0.0002	0.018 ± 0.0016	0.013 ± 0.001	0.005 ± 0.0004	0.0046 ± 0.0002	0.008 ± 0.0001

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SIMULATION OF X RAY IRRADIATION ON HUMAN HAND

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Abstract

Using the Monte Carlo code MCNP we simulate a human hand X-rays irradiation with radiodiagnostic energies. We calculate bone dose considering a soft tissue –water- and calcium bone hand, which is irradiated with a million of X-rays photons, which leave from a punctual source. These photons are directed and distributed inside a conic angle on the hand. Afterwards, we simulate elements which normally compose bones (C, H, O, N, Mg, P, Ca, and S). We estimate bone dose considering: a) bone material (water, calcium and bone tissue); b) bone thickness (0,01; 0,1; 0,5; 1,0; 1,5 and 3,0 cm); and c) source-hand distance (30, 50, 70 and 90 cm). We calculate photon transmission percent through soft tissue and bone tissue and the statistics from the number of photons that reach the radiographic film after going through soft tissue or bone tissue for our geometric configuration. We find that we can obtain a good image contrast in the range of 20 to 40 keV energy X-rays photons.

We used the MCNP Monte Carlo code for the simulation of a human hand X-rays irradiation with radiodiagnostic energies.

We calculate bone dose considering a human hand with soft tissue –water- and bones composed with biological tissue -C, H, O, N, Mg, P, Ca and S-. Our geometry considers a hand irradiated with a million of X-rays photons from a punctual source at a distance of 70cm. These photons are directed and distributed inside an air conic angle on the hand. To economy computing time, we consider empty the part outside the cone.

For the physics interpretation from the results obtained with the MCNP code, we performed a bone dose estimate considering: a) bone material (water, calcium and bone tissue); b) bone thickness (0,01; 0,1; 0,5; 1,0; 1,5 and 3,0 cm) and c) source-hand distance (30, 50, 70, 90 cm).

We calculate photon transmission percent through soft tissue and bone tissue from the number of photons that reach the radiographic film after passing through soft tissue or bone tissue for the human hand and its geometric configuration.

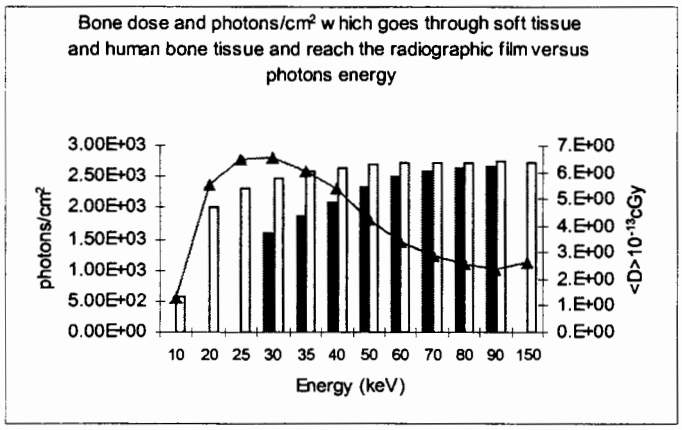

Fig.1. Average bone dose x10^{-13} cGy in hand (▲) and photons/cm^2 which reach the radiographic film after goes through soft tissue (empty bar) and human hand bone tissue (solid bar) versus energy (keV) from a X-ray source of a million of photons.

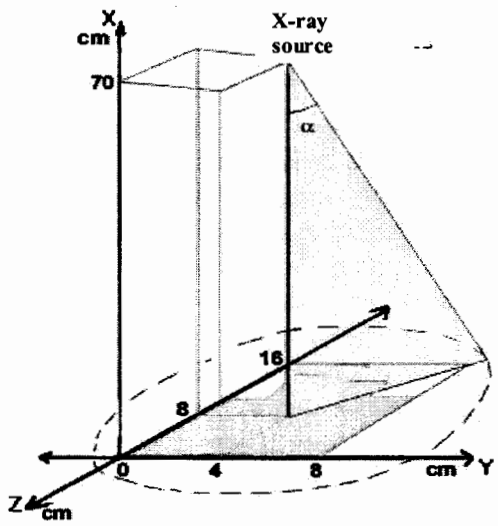

Fig.2. Geometric configuration for simulation of x-ray irradiation on human hand with radiodiagnostic energies from a million of photons from a punctual source. Irradiation is considered in a cone with angle α =9°. The distance between the source and hand is 70cm.

The transmission of photons varies with the type of tissue and photon energy. If the transmission is very low, then few photons will reach the image receptor and the radiation dose to the tissue will be high. When the difference in transmission through different types of tissue is little, the contrast in the image will be poor. We can obtain a good image contrast in the range of 20 to 40 keV energy X-rays photons. The choice of energy will be a compromise between the requirements of low dose and high contrast. We proved that 40 keV allows us a radiographic image hand with a better quality and low tissue bone dose. See Fig. 1.

Radiation injury of the skin following diagnostic and interventional fluoroscopic procedures

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Abstract:
Many radiation injuries to the skin, resulting from diagnostic and interventional fluoroscopic procedures, have been reported in recent years. In some cases skin damage was severe and debilitating. We analyzed 72 reports of skin injuries for progression and location of injury, type and number of procedures, and contributing patient and operator factors. Most cases (46) were related to coronary angiography and percutaneous transluminal coronary angioplasty (PTCA). A smaller number was documented after cardiac radiofrequency catheter ablation (12), transjugular intrahepatic portosystemic shunt (TIPS) placement (7), neuroradiological interventions (3) and other procedures (4). Important factors leading to skin injuries were long exposure times over the same skin area, use of high dose rates, irradiation through thick tissue masses, hypersensitivity to radiation, and positioning of arms or breasts into the radiation entrance beam. Physicians were frequently unaware of the high radiation doses involved and did not recognize the injuries as radiation induced. Based on these findings, recommendations to reduce dose and improve patient care are provided.

1. Introduction

The number of interventional cardiologic and radiologic procedures performed under fluoroscopy has grown markedly worldwide during the last decade [1]. Advances in interventional techniques have made more complex procedures possible. This trend results in increased fluoroscopy use and is accompanied by a sharp increase in the number of reported skin injuries. We reviewed over 70 case reports of skin injuries that resulted from fluoroscopic procedures [See, for example, reference 2]. More than 90% of cases were reported since 1996. Although the absolute number of injuries may appear very small when compared to the more than 700,000 interventional procedures performed annually [1], skin damage is likely to be under-reported. The main reason is widespread unawareness of this radiation effect and consequent inability of physicians to correctly diagnose it. Radiation damage can be serious. Chronic ulceration and tissue necrosis were documented in about half of all cases. The purpose of our review is to describe these injuries and to investigate common factors related to the patients and their procedures that may have led to the injuries.

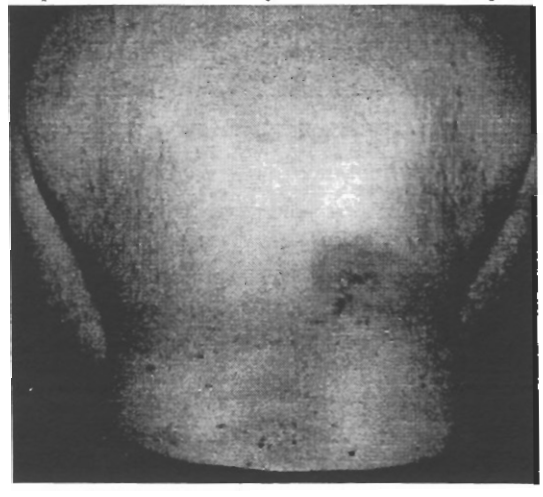

Fig. 1. Well demarcated erythema in large-chested man after PTCA of right coronary artery using stationary left anterior oblique and slightly cranial x-ray beam orientation

2. Skin injuries

Radiation induced skin injury is usually not observed immediately after a procedure, but after a characteristic latent period in which the patient can be free of symptoms. The latent period is most often in the range of 2 weeks to 3 months, but varied in the reviewed case material from a few hours to more than 3 years. Skin injury represents a deterministic radiation effect that requires a radiation dose above a certain threshold. The following radiation skin effects were observed and are given in order of their time of onset (threshold doses are given in brackets).

Skin erythema can occur within hours (early transient erythema, 2 Gy) or after 10 days (main erythema, 6 Gy). When a single fixed beam orientation is employed, lesions are typically sharply defined and match the entrance port of the radiation beam (Figure 1). Epilation can be seen after 3 weeks and can be temporary (3 Gy) or permanent (7 Gy). Erythema and epilation are early signs which, when observed, can serve as a warning signal indicating that a certain threshold has been exceeded.

After 4 weeks dry or moist desquamation (14 Gy and 18 Gy respectively) can occur. Secondary ulceration (24 Gy) may arise after about 6 weeks, ischemic dermal necrosis (18Gy) after 10 weeks. Prophylaxis against local infection is essential in these cases. Wound healing is typically prolonged and less efficient due to microvascular radiation damage in the dermis, which leads to a relative ischemia. Ulcers which have slowly healed over an extended period of time have a tendency to recur, often provoked by trivial trauma. One of the problems of radiation ulcers is that they can increase in size and depth despite all treatment. Pain control can be a difficult task to achieve. Several cases are known to the authors in which deep tissue necrosis extended to involve muscles and bones. In at least 4 cases deep tissue ulceration was present for more than a year.

In a substantial number of reviewed cases (23%), wound healing could not be achieved despite intensive wound care. Skin grafting finally had to be performed (Figure 2). In a number of cases the initial graft was unsuccessful. Skin grafts are often complicated in these cases by the compromised vascular supply.

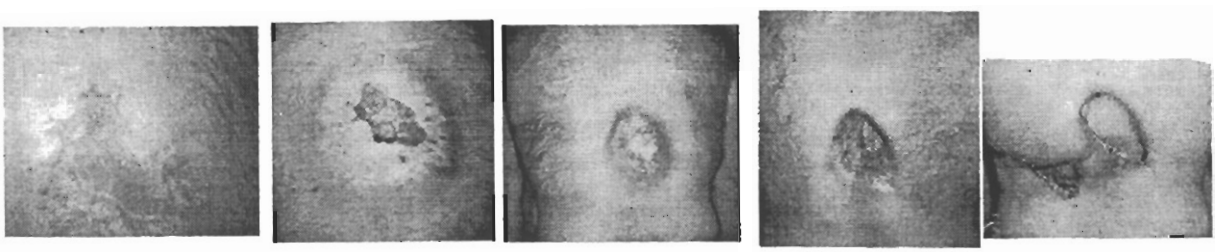

Fig. 2. Progression of injury in heavy-set male following TIPS procedure. From left to right: injury at 4 months; 7 months; 9 months; 22 months; 23 months.

Late radiation sequela, which can be seen after 3 months to more than a year, are dermal atrophy (10 Gy) and telangiectasia (10 Gy). These, together with areas of hyper- and hypopigmentation, give the skin a poikilodermic appearance. Subcutaneous induration results from a relative increase in the fibrous component of the tissues and can be painful. It may limit motion of it occurs close to a joint (e.g. at the shoulder in cardiac procedures).

We noticed radiation skin injuries at the breast in two female patients after interventional cardiac procedures. One patient was only 17 years old. Breast tissue in the adolescent is among the most sensitive tissues for development of radiation induced malignancies. This will significantly increase the patient's statistical risk for breast cancer in the future.

3. Which procedures have a potential of skin injury?

Out of 72 reviewed cases of fluoroscopically induced skin injuries, 46 cases (63%) were related to coronary procedures. The majority of these (43 patients) underwent percutaneous transluminal coronary angioplasty (PTCA). The high proportion of this procedure in the total number of reported cases reflects the high number of annually performed cardiologic interventions that far outweigh other

interventional procedures (700,000 coronary procedures versus 30,000 other procedures). In decreasing order of prevalence, the location of the skin injury was: right and left scapular or subscapular area, right lateral chest below axilla, midback, and right anterolateral chest. The site of the injury corresponds to the site of the entrance beam and reflects the beam orientation predominately used during the procedure.

A smaller number of skin injuries was caused by cardiac catheter radiofrequency ablation (12 patients), transjugular intrahepatic portosystemic shunt (TIPS) placement (7 patients) and neuroradiological interventions (3 patients). The skin injury involved the back and arm in patients undergoing ablation and the midback and right subscapular area in patients undergoing TIPS procedures. Four patients had other interventions in the abdomen or chest. However, any fluoroscopic intervention has the potential to cause injury if the radiation dose exceeds the deterministic threshold.

4. What factors contribute to the injury?

In many reports, a substantial delay occurred between the initial moment the patient presented skin with changes to a physician and the moment the physician made the correct diagnosis. Physicians did not initially associate the injury with radiation from fluoroscopy. Patients were treated in the interim, without success, for a variety of other suspected causes. Meanwhile, some patients underwent a second fluoroscopically guided intervention with additional exposure to the same area. The correct diagnosis was sometimes delayed by several years, in one case the delay was more than 5 years. The latency period between the last intervention and the first appearance of the skin lesion probably contributes to the delay in diagnosis, as the physician is less likely to consider radiation as the etiology.

Several reports originating from radiation therapy literature indicate a correlation between certain diseases and an exaggerated radiation complication after treatment. These include connective tissue diseases (scleroderma, lupus erythematosus, mixed connective tissue disease), diabetes mellitus, hyperthyroidism and the homozygous form of ataxia telangiectasia [3]. Some chemotherapeutic agents are also known to increase sensitivity to radiation [4, 5]. A few reports from interventional work now cite these as probable sensitizing factors for some observed skin reactions.

Long exposure time to the same skin area was the most prevalent factor among the reviewed cases that resulted in skin injuries. Procedures were often difficult or prolonged due to complications, such as arterial dissection.

Extensive use of high magnification or high detailed-mode led to high dose rates. In some cases of skin injury, the physician used these modes exclusively. Cinefluorography is associated with a 10 times higher dose rate per imaging frame than conventional fluoroscopy. High doses can accumulate within minutes during this imaging mode.

Irradiation through thick masses of tissue increases the skin dose. Large patients, common in our study group, are therefore at higher risk for radiation damage. In a similar way, beam angulation increases the tissue pathlength for the x-rays to penetrate and puts the skin closer to the x-ray source. The skin dose, for example, increases by a factor of 4 when 30° cranial angulation are added to a 40° left-anterior-oblique (LAO) projection in a cardiac procedure [6]. Steep beam angles were frequently employed in the reviewed case material and contributed to the reported injuries.

In three cases of radiofrequency ablation procedures, radiation injuries were observed on the arm. In two cases, involving different procedures, skin lesions appeared on the breast. During the procedures these body parts were in the primary radiation beam in close proximity to the x-ray tube, resulting in very high skin doses.

In three cases equipment malfunction or other deficiencies were causative factors for the injuries.

5. What can be done to reduce the risk?

Physicians must be able to identify radiation-induced skin injuries in patients. Prior to performing a procedure, a detailed history of prior fluoroscopic interventions and any observed skin effects is essential. If the patient has had such procedures, a brief inspection of the skin is appropriate. The diagnosis of radiation-induced skin injury can often be made based on history and physical examination. Areas of skin injury are usually well defined and occur in typical locations. A skin

biopsy may sometimes be helpful in excluding other causes, but should not be performed as part of "routine work-up" as they may result in a nonhealing ulcer.

Interventionalists must keep fluoroscopic on-times to a minimum. Fluoroscopy times or the actual radiation dose should be monitored. Normal values should be established for each procedure. If a procedure is more complicated than expected, or if the fluoroscopy times or radiation dose exceeds a certain limit, consultation with more experienced staff should be sought.

Pulsed fluoroscopy and heavy beam filtration provides imaging at a significantly reduced radiation dose and its use is highly recommended. The dose can be lowered by 50-70% with no perceivable loss in image quality.

Image magnification, high-resolution settings and cineangiography should be used and judiciously and sparingly.

If a procedure proves to be lengthy, the incident beam angle should be varied in order to expose different areas of skin. This will be effective only if the field of view is minimized by collimation. Otherwise different projections will lead to overlapping radiation fields. General rules of dose reduction must be followed, e.g. the image intensifier should be kept as close to the patient as possible, the distance between x-ray tube and patient should be kept large. If large air gaps between the patient and image intensifier cannot be avoided, the grid should be removed, if possible, as it only adds to additional radiation without effective function.

Extraneous body parts, such as an arm or a female breast, have to be positioned and secured in a way that they will not be exposed in the primary x-ray beam.

Real-time dose monitoring enables the physician to recognize high dose levels and is recommended. The physician can take action to lessen the dose rate early if the dose monitor indicates high radiation levels. Dose monitors also keep track of doses from fluorography and eliminate the need to monitor fluoroscopy time. Increased output due to equipment malfunction can be recognized.

Patients who receive a high skin dose (e.g., in excess of 3 Gy) should be counseled and advised on examining their skin at the proper location. If any skin changes are observed, the patient should contact the physician who performed the procedure.

A good quality control program should be established to assure high standards in dose reduction and image quality.

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PATIENT DOSES FOR COMPUTED TOMOGRAPHY IN HUNGARY

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ABSTRACT

The latest initiative of the National Patient Dose Evaluation Program was an overall evaluation of patient doses for computed tomography. The aim of the survey was to collect data from which the patient doses of the CT examination of different body parts can be estimated and the most important technical parameters affecting on the patient exposures can be evaluated. The 54 CT scanners in clinical use in Hungary can be categorized into 31 different models from 8 manufacturers. Per caput frequency for CT is about 62.3 examinations per 1000 inhabitants. 59% of all examinations are connected to the head imaging. The highest mean effective dose arising from the chest and pelvis examinations, 6.98 mSv and 6.64 mSv, respectively. The yearly collective effective dose has been estimated at about 1700 manSv. This total dose is as much as the figure of 1785 manSv previously assessed for photofluorography applied in mass chest screening in Hungary.

1. INTRODUCTION

The results of surveys from the most developed countries show that the frequency of CT examinations and consequently the collective dose are increasing steadily, constituting a significant part of the collective dose of the population arising from the medical applications of ionizing radiation [1-3].

Diagnostic importance of CT examinations is outstanding, so the increase of examination frequency is justified. According to the International Commission on Radiological Protection (ICRP) dose limits should not be applied for medical exposures either diagnostic or therapy, because patients have direct benefit from the exposure. However according to the basic principles of radiation protection the medical diagnostic procedures should be optimized and unjustified exposures should be minimized [4,5].

Since the beginning of the eighties computed tomography (CT) plays a significant role in medical diagnostics in Hungary too. According to the records there are 54 CT scanners in clinical use in Hungary which can be categorized into 31 different models from 8 manufacturers.

2. METHODS

In the two stages of the survey program scanner specific dosimetric data and examination specific data were collected. Free-in-air and phantom doses were measured by a special pencil-shaped ionization chamber coupled to the electrometer (type 1015 10.3CT, Radcal Corp., California, USA). The phantom measurements were made in PMMA head and body phantoms -

16 cm and 32 cm diameter, respectively - at the center of the phantom and at 10 mm beneath the surface. In addition to the phantom measurements, free-in-air measurements in the rotation center were made.

According to the minimum survey program, the dose measurements were made on the two most frequently used tube voltages, at the minimal, the maximal and 2 mm slice thickness. At workplaces where we had more time this dose collection program were extended to additional slice thickness.

The clinical performance was investigated by monitoring all CT examinations during one week, comprising all relevant technical and clinical data. The collected data were partly patient related: sex, year of birth, body height and weight of the patient, diagnostic purpose of the examination, body region examined and use of contrast agent. The exposure related data were as follows: scan mode (axial or spiral), gantry tilt angle, tube voltage and loading, slice thickness, table movement increment or pitch factor, number of scans and the start position of the scans.

From the measured dosimetric data the Computed Tomography Dose Indexes, $_nCTDI_{air}$ and the $_nCTDI_{w,body}$ were calculated on each relevant tube voltage and slice thickness.

The CTDI for each patient examination was calculated from the relevant value of $_nCTDI_{w,body}$ data multiplied it by the tube loading C used in the patient examination. The CTDI gives the average dose per slice to the patient. The dose-length product (DLP) was calculated from the CTDI multiplied it by the slice thickness and the number of slices [6,7].

The effective dose of patient exposure was calculated applying the normalized values of effective dose per dose-length product over various body regions.

3. RESULTS

Typical patient attendance for individual scanners varied in a wide range with a mean for the sample of around 110 patients per week. These data indicate an annual total of 623000 CT examinations in 1999 from the 54 scanners in operation, involving 303000 patient attendance. It is an important fact that in our survey a CT examination means a sequence of scans with identical technical parameters of tube voltage, tube loading, slice thickness etc. The corresponding per caput frequency for CT is about 62.3 examinations per 1000 inhabitants.

Frequency data for different types of examination shows that 59% of all examinations are connected to the head imaging (see Figure 1.). The next most important region of the body in terms of examination frequency is the abdomen, which represents 23% of all examinations, with smaller contributions from the chest (12%), and pelvis (4%).

Representative information on the age and sex of patients undergoing CT has been obtained from a sample of 2052 patient records. The shapes of general distribution for patients undergoing CT indicate a bias towards relatively elderly persons compared with the general population. The average age of CT patients and the general population of Hungary is 54 and 39 years, respectively. The percentages of CT patients aged over 43 years and over 64 years are 75% and 25%, respectively. The significant number of older CT patients has important implications for the expression of delayed radiation effects. The 49% of CT patients were male and 51% of them were female.

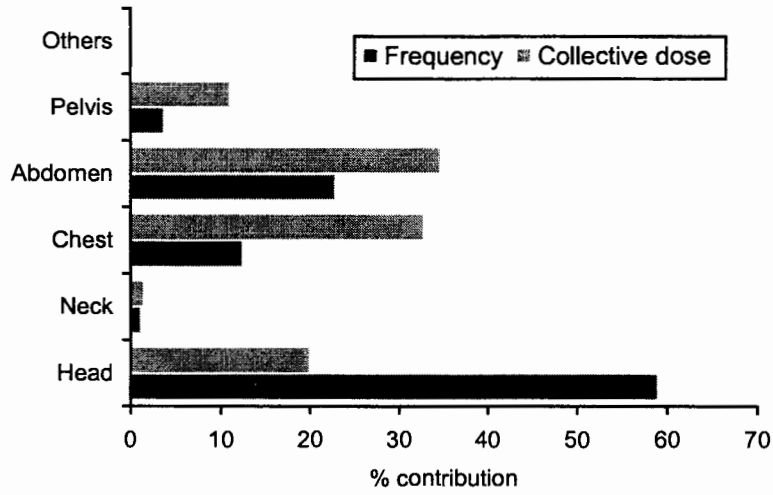

Figure 1. Contribution to CT practice by examination type

Effective dose from CT by examination type can be seen in Figure 2. The highest mean effective dose arising from the chest and pelvis examinations, 6.98 mSv and 6.64 mSv, respectively. There is no significant difference between their figures. The CT examinations of the abdominal region cause about 3.7 mSv mean effective dose. The CT examinations of the head performed with the highest frequency account for only 0,83 mSv mean effective dose.

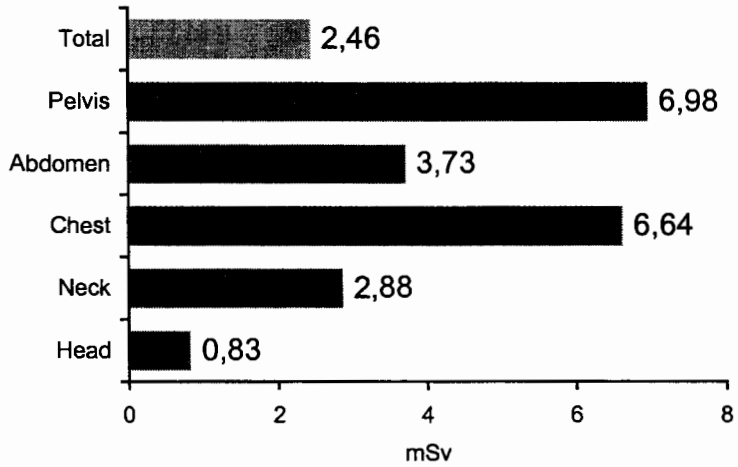

Figure 2. Effective dose from CT by examination type

A relatively wide variation can be observed in mean effective doses for examinations between workplaces, which can be explained by the variations in inherent parameters of scanners, the technical parameters and the frequency distribution of different type of examinations.

The collective effective dose from the 54 scanners operating in Hungary in 1999 has been estimated at about 1700 man Sv. This total dose is as much as the figure of 1785 man Sv previously assessed for photofluorography applied in mass chest screening in Hungary [8]. The consequent average effective dose per CT examination of about 2.5 mSv was estimated (see Figure 2.). Consequently, each scanner gives rise to a collective dose of about 32 man Sv a year.

Contributions to the collective effective dose from CT by examination type can be seen in Figure 1. Whereas examinations of the head represent nearly 60% of all CT examinations, they account for only 20% of the collective dose, which is dominated by examinations of the abdomen and the chest.

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MEDICAL MANAGEMENT OF RADIATION SAFETY AND RADIOLOGICAL PROTECTION OF PATIENTS IN ARMENIA

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ABSTRACT: The events of the last 10 years, Spitak earthquake (1988) and collapse of the Former Soviet Union brought forth the changes of the political situation in Armenia and significant disorder in economy, industry, relations, environmental and public health, including the radiation safety (RS) and control of patients in general diagnostic radiology.

In Armenia there are about 750 X-ray rooms, 10 radionuclide diagnostic laboratories, 20 gamma and X-ray units. 95 enterprises in industry, science and technology use the Ionizing Radiation Sources (IRSs) with different purposes; there are 5 electron particle accelerators of different power capacity.

About 6,000 individuals have constant contact to IRS: the roentgenologists, radiologists, the staff of Armenian Nuclear Power Plant and that of the accelerators, etc. Besides, more than 3,000 liquidators of the Chernobyl NPP disaster live in Armenia.

Nowadays, the precise infrastructure of RS is established in Armenia. The regulating body is the "State Atom Authority", performing the control, coordination and licensing of both enterprises and specialists. Ministry of Health, Ministry of Internal Affairs, and Ministry of Ecology perform the control of IRSs' delivery into the Republic of Armenia and then their proper use and waste disposal in Armenia.

MANUSCRIPT: In Armenia the integration of radioactive technologies into science, engineering and medicine (for the purposes of diagnostic radiology and radiotherapy) began in 1960s, in parallel to the progress of the above-mentioned branches of the former USSR. The RS, monitoring and control over the works performed with the use of IRSs were exercised and centralized by the bodies of Sanitary Epidemiological Supervision on RS monitoring of the former USSR.

In 1976 the Armenian Nuclear Power Plant (WEP-440 type) was constructed. Reactor I was started up in 1976 and Reactor II - in 1980. In 1989 the NPP was shut down after the disastrous Spitak earthquake. Due to the energy crisis in Armenia it was restarted to supply power in 1994.

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*Professor Nikoghos M. Hovhannisyan, D.Sci. (Med.), Director of the Centre.

There are some 750 X-ray rooms, 10 radionuclide diagnostic laboratories, 20 gamma and X-ray units in Armenia. 95 enterprises of industry, science and technology use the IRSs for various purposes. There are 5 electron particle accelerators of different power capacity. However, during the past few years no radionuclide researches are carried out, the number of X-ray rooms decreased due to the critical economic situation in our country.

In Armenia about 6,000 individuals have constant contact to IRSs: roentgenologists, radiologists, the staff of NPP, the accelerators, etc. Besides, more than 3,000 residents of the Republic responded to the liquidation of Chernobyl NPP disaster and are on a register for prophylactic medical follow-up at the Research Center of Radiation Medicine and Burns (RCRM&B). The entire infrastructure of RS is created in Armenia. The regulation body in this concern is the "State Atom Authority" supervising the execution, coordination and licensing the enterprises and specialists.

Much attention is devoted to radiation safety at Armenian NPP, performed by self dependent department of RS immediately at the NPP.

Much prominence in ensuring the RS belongs to Ministry of Health, the regulating control is provided by its Department of Hygiene and Epidemiological Supervision in concern of radiation situation and licensing of specialists in the system of Public Health. The safety of IRSs at the enterprises, their transportation and wastes disposal, permissions for the receipt, storage and rights to perform activity are conferred and controlled jointly with Ministry of Internal Affairs. All the dosimetric and radiometric researches are carried out by the department of RS of the Center.

Both the Environmental Control and Monitoring of radiation background are performed by the appropriate subdivision in the structure of Ministry of Ecology and Hydrometeorology.

The management of medical assistance in a case of radiation emergencies is carried out by RCRM&B.

Nowadays, as a WHO Collaborating Center, RCRM&B performs the following activities:

1. serves as a basic/focal point for medical care in cases of human radiation injuries;
2. carries out training of specialized staff in radiation medicine, radiation hygiene and radiobiology;
3. performs the development and planning of all the measures on medical assistance in the event of radiation accidents;
4. coordinates researches on radiation medicine and radiobiology;
5. develops plans and normative relevant documentation.

6.

In case of an accident the RCRM&B is prepared to:

- promote the team for on-site first aid to the emergency victims;
- promote the dosimeter control group to study the radiation contamination level of the area;
- perform the arrangement ("assortment") and transportation of those injured (radiation contamination accident victims);
- carry out the diagnosis and treatment:
  a) by means of biodosimetry (bioassay),
  b) by means of radiometry with the use of whole body counter;
- render specialized medical aid to wounded and injured persons.

In practice the RCRM&B functions as an All-Armenian Center on diagnostics and treatment of general and local radiation injuries, RS and population protection. The RCRM&B is constantly preoccupied by elaboration and improvement of methods of prophylaxis, diagnostics and therapy of radiation injuries, as well as bioindication. Great importance is given to the studies of the impact of low dose radiation action.

Taking into account all the above-mentioned, in 1995 the Department of burns was created at the RCRM&B, functioning now as a Center of Burns (CB). It would also promote assistance in a case of a radiation accident. Now the CB admits patients not only from all the districts of Armenia, but from other countries of the region as well.

Nowadays, with the assistance of IAEA a number of Projects are performed at the RCRM&B with the assistance of IAEA on RS, radiation medicine and Training Programmes.

third quartile values of the dose distributions had dropped by about 30 percent since the national survey in the 1980s [3].

4. Conclusion

RDLs are a valuable tool to achieve patient dose reduction. However, the different approaches met in practice clearly indicate a need for harmonisation.

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EVALUATION OF THE RADIATION DOSE IN A PAEDIATRIC X-RAY DEPARTMENT

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1. Abstract

This is an on going study that is conducted for the first time in Cyprus, whose objective is to compare radiation doses received by children during radiological examinations from a dedicated paediatric X-ray unit, with those from other departments around the world and reduce them if needed.

Radiation doses were measured simultaneously for comparison purposes, with extremity thermoluminescent dosimeters (TLD) type TLD-100 Lithium Fluoride and with a dose area product meter, (DAP), Gammex-RMI Inc, Model 841-S. Data recorded for each radiological examination are age, sex, weight, height, focal size used (small/large), source image distance, (SID), technique used (manual/automatic), kVp and mAs.

The radiation doses received by children, undergoing chest examinations are presented and compared.

2. Introduction

It is generally accepted today, that although dose limits do not apply for patients, dose reference levels should be followed as a guide and an aid to the optimisation of radiation protection in medical exposures. The imaging process must be optimised, once the diagnostic examination has been justified and this involves three aspects :

- the choice of radiographic technique
- the diagnostic quality of the radiographic image
- radiation dose to the patient [1]

If the patient is a child the risk of detrimental effects from ionising radiation, is greater than that of adult patients [2].

Therefore, it is of the utmost importance, that radiation doses, especially paediatric, are kept at a minimum level, without significant deterioration of the image quality and of the diagnostic value of the examination.

These are the first results of an ongoing study in which the doses are measured with two methods, TLD dosimeters and DAP meter.

3. Materials and Methods.

This study is carried out at the Radiology Department of the Makarios III Hospital in Nicosia, Cyprus. This is a Mother-and-Child Hospital with a dedicated paediatric department. The X-ray system used is a paediatric unit, which allows the possibility of beam filtration changes to be done easily, is a high frequency Philips Super 80 CP, with a SRO 33 100 type tube and total filtration 3.3 mm Al.

The processor is a Kodak PRX X-OMAT, model M6B set to give a γ of 3.29 and a G of 2.12. The cassettes used are Okamoto type, High Speed 250.

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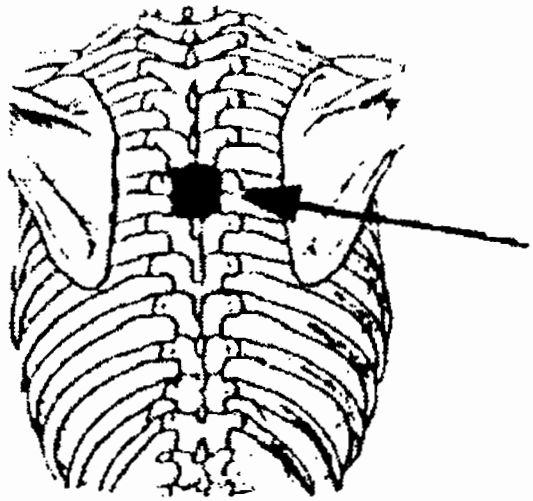

TLD Chip

Figure 1. Diagram of TLD placement for Chest PA examinations.

The DAP meter used is the Gammex-RMI Ltd, model 841-S. This is a full field Ion Chamber with a sensitivity of 130 pC/mGycm^2. The dose area product rates are 1 mGycm^{2}s^{-1} to 400.000 mGycm^{2}s^{-1}. The DAP meter with a transparency of greater than 75% was attached to the collimator of the X-ray tube.

Table 1. Comparison between our examination parameters and patient set-up, with those of the European Guidelines on quality criteria for pediatric chest examinations, for the 5-10 years old, age group.

Radiographic Technique	E.C. Guidelines	This Study
Patient position	upright, supine position possible	upright
Radiographic device	table or vertical, depending on age	vertical
Nominal focal spot value	0.6 (less or equal to 1.3)	small focus 0.6 large focus 1.3
Additional filtration	up to 1mm Al +0.1 or 0.2 mm Cu (or equivalent)	2mm Al
Antiscatter grid: r=8; 40/cm	only in special indications and in adolescents	fixed oscillating grid : r=12; 36/cm
Screen film system	nominal speed class 400-800, FFD 100-150 cm	nominal speed class 250, FFD 150cm
Radiographic voltage	100-150 kVp with grid	96-109 kVp with grid
Automatic exposure control	chamber selected-lateral	chamber selected-lateral
Exposure time	< 10 ms	< 10 ms
Protective shielding	lead rubber coverage of the abdomen in immediate proximity of the beam edge	no added protective shielding

The TLD's used are Chipstrate Dosimeters from Harshaw/Bicron. They consist of a $^1/_8 x ^1/_8$ inch TLD chip hermetically bonded to a polymide substrate, to which an ID bar code strip is attached. The TLD material is TLD-100 LiF natural, nearly tissue equivalent with a measurement range 10μGy to 1 Gy. These are placed on the patient as shown in figure 1, according to the European Commission guidelines [1].
The measuring instrument used for the quality control inspections is the Keithley Model 35080A kVp divider, which is compared and calibrated against the secondary standard, at the Nicosia SSDL, which is situated at the Nicosia General Hospital.

The parameters recorded for each examination are : Type of examination, sex, weight, height, age, kVp, mAs and focal size (small or large) used.

The initial examination parameters and patient set-up used, are compared with those recommended by the European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics of the European Commission, as shown in Table 1, for the 5-10 years age group for chest examinations.

Our initial Chest Technique set up deviate from the European Guidelines in three parameters :

Additional Filtration

Screen Film Combination

Protective Shielding

The intention of the study was first to measure the doses with the existing set up and then make modifications to the technique in steps. At each modification step to measure the doses, in order to compare the effect of each modification.

4. Results

The results obtained so far are shown in Table 2, which give the mean dose results obtained by the TLD and DAP dosimeters. The results presented are in terms of Entrance Surface Dose ESD_{TLD} and ESD_{DAP}.

ESD_{TLD} is expressed in terms of absorbed dose to air which is equivalent to entrance air kerma at diagnostic x-ray energies. The associated uncertainties for chest examinations are 20% and 31% respectively. These results are compared with those of similar studies carried out elsewhere.
The orthochromatic cassettes used in the first modification step are the KB69050-F PTM Kodak, Lanex X-OMATIC with a speed of 400.

The beam filtration used in the second modification step was increased to 0,1 mm Cu + 1,0 mm Al.

5. Discussion of results

The results obtained with the initial set up, show that the radiation doses delivered to children appear to be higher than those in other studies. Nevertheless all our TLD results are however less than the maximum value reported by the National Council on Radiation Protection and Measurements report No 68 [3], which for a 10 year old child, was 0.5 mGy for the same type of examination.

The results obtained after the first modification, are substantially improved with the DAP measurements falling within the range of values of the Irish study. The TLD measurements are still higher than the other studies and twice the values of the Irish study.

Table 2. Comparison of doses for chest X-ray examination, between three different studies, for the 5-10 years old age group, in terms of ESD $_{TLD}$ and ESD $_{DAP}$. Figures in parenthesis give the range of values.

Study	*Sample Size*	*Mean ESD_{TLD} (mGy)*	*Mean ESD_{DAP} (mGy)*	**Comments**
UK	***(N/A)***	***0,06 (N/A)***	***34 (N/A)***	
Ireland	***30***	***0,046 (0,032 – 0,087)***	***23 (10 – 65)***	
Cyprus	***13***	***0,14 (0,09 – 0,23)***	***80 (40 – 218)***	***Original Set Up***
Cyprus	***24***	***0,089 (0,070 – 0,147)***	***24 (18 – 48)***	***With Orthochromatic Cassettes***
Cyprus	***13***	***0,079 (0,058 – 0,119)***	***20 (10 – 58)***	***With Orthochromatic Cassettes and increased beam filtration (0,1 mm Cu+1,0 mm Al)***

The results obtained thus far after the second modification are even better with the DAP measurement being below those of the Irish study and the range of the TLD measurements so far are within the range of the Irish study but the average value is still higher than that of the Irish study.

The above modification had no visible effect whatsoever on the quality of the radiograph produced, which has ben verified by the Radiologist in charge.

6. Conclusion

The practice as used initially in this study is improved by reducing the radiation dose to be within the European Commission Guidelines. This was achieved by using ultra high speed cassettes and by hardening the radiation beam with increase of the filtration. The doses can further be reduced by using higher kVp techniques and by removing the oscillating grid during paediatric use of the unit, as it is recommended in the European Guidelines.

7. Acknowledgments

This study is supported by the Biomedical Research Foundation, Nicosia Cyprus. The support and assistance of the personnel of the Radiology Department of the Makarios III Hospital is acknowledged and specially to Radiographers, Vathoulla Ioannou, Stella Komodromou, Stavroulla Karapataki, Eleni Evangelou and Dark Room Technician Nicos Loizou.

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IONIZING RADIATION USED IN MEDICAL DIAGNOSTICS AS A SOURSE OF A RADIATION EXPOSURE OF THE PATIENT WITH OCCUPATIONAL DISEASES. ANALYSIS AND PROBLEMS

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Abstract

X-rays in medical diagnostic are the major source of bulgarian population exposure to ionizing radiations. Diagnostic X-ray is the most diagnostic application and is used in wide variety of examination. The modern concept for radiation protection of patients in diagnostic radiology is based on two main principles: justification of the examinations and radiation protection optimization. It is pointed out that the collective effective dose of radiation may be considerably reduced by decreasing the number of clinically unwarranted X-ray examination of storage and delivery of diagnostic information and adopting a system for physical and technical quality control of the X-ray equipment.

The aim of this investigation is assessment the collective effective doses for the patients with occupational diseases, exposed to ionizing radiation by radiological diagnostics.

The study covers the period of 1990 through 1999. A total of 3293 patients, treated in Department of occupational toxicology, Clinic of occupational diseases, Medical University-Sofia were examined with X-ray and KT (cervical and lumbar spine, chest, skull, stomach, extremities, pelvis, brain). The most of the observed patient were with heavy metals poisonings predominantly and a little with other chemical agents poisonings. Number of patients with radiological examinations was 1938, number of examination per capita was 0,59 and the total number of radiological examinations was 2536. The average number of radiological examination for one patient was 1,36, the most number of radiological examination for one patient was 4. The collective effective dose for an examined patient was 1803 man.mSv. Our results shown the essential of the raising ensure that the medical exposure of patients be the minimum necessary to achieve the required diagnostic objective.

Key terms: radiological diagnostic, medical exposure, collective effective dose, occupational patients, optimization of radiation protection.

Introduction

In many branches of medicine, ionizing radiation is a powerful tool both as an aid to diagnosis and a means of therapy. Diagnostic X-ray is the most familiar application and is used in wide variety of examination. X-rays in medical diagnostic are the major source of bulgarian population exposure to ionizing radiations. It has been estimated that over 90% of the total exposure of the bulgarian population from uses of radiation comes from the diagnostic use of X-rays [1,2,3].

There are two categories of biological effects of ionizing radiation: deterministic and stochastic effects. For stochastic effects no threshold dose is assumed and the probability of their occurrence is believed to the proportional to the dose (linear dose-effect relationship in the low dose, low dose-rate range). The probability of a fatal radiation induced cancer has been estimated at approximately 5 per cent per Sievert effective dose for the low dose, low dose-rate and 1% for serious genetic diseases, for the whole population with is normal age distribution. Many organs are believed to be sensitive to stochastic effects, notably the gonads, female breast, bone marrow, lung, thyroid and bone surfaces [4,5,6].

The modern concept for radiation protection of patients in diagnostic radiology is based on two main principles: justification of the examinations and radiation protection

optimization. It is pointed out that the collective effective dose of radiation may be considerably reduced by decreasing the number of clinically unwarranted X-ray examination of storage and delivery of diagnostic information and adopting a system for physical and technical quality control of the X-ray equipment [7,9].

The aim of this investigation is assessment the collective effective doses for the patients with occupational diseases, exposed to ionizing radiation by radiological diagnostics.

Materials and methods

The study covers the period of 1990 through 1999. A total of 3293 patients, treated in Department of occupational toxicology, Clinic of occupational diseases, Medical University-Sofia were examined with X-ray and KT. The examination considered: chest PA (posterior-anterior) and LAT (lateral) projections, cervical spine AP (anterior-posterior) and LAT projection, lumbar spine AP, LAT and LSJ (lumbo-sacral-joint) projection, skull- PA and LAT, hand and wrist AP, pelvis AP, Ro-contrast stomach, KT brain. The most of the observed patient were with heavy metals poisonings predominantly and a little with other chemical agents poisonings.

For an assessment of the collective effective dose, the radiological examined patients were distributed by age, number of radiological examinations, and structure of radiological diagnosis.

Number of patients with radiological examinations was 1938, number of examination per capita was 0,59 and the total number of radiological examinations was 2536.

Results and discussion

The number of treated patients, the number of patients with radiological examinations, the total number of conducted radiological examinations, and the number of radiological examinations for one patient, distributed by the observed years are shown in Table I.

Table I. Number of treated patients, patients with radiological examinations, total number of conducted radiological examinations, and radiological examinations for one patient.

Year	Number of treated patients	Number of examination patients	Number of radiological examinations	Number of examinations for one patient
1990	331	195	265	1,35
1991	342	202	273	1,35
1992	347	204	255	1,25
1993	335	189	246	1,30
1994	342	201	281	1,40
1995	348	202	272	1,35
1996	342	202	282	1,40
1997	338	201	251	1,25
1998	328	198	257	1,29
1999	246	153	214	1,39
Total	3299	1938	2596	

The results in the Table I shows the average number of radiological examination for one patient was 1,36, the most number of radiological examination for one patient was 4. The ratio (number of treated patients)/(number of radiological examinations) is 0,58.

The distribution of the treated patients by the age and sex for 1998 is presented in Table II. The structure of radiological diagnosis and collective effective doses are presented in Table III.

Table II. Distribution of the number of treated patients by the age and sex for 1998y.

Age of patients	Number of patients		Total	Number of radiological examinations		Total	Number of examinations per capita
	man	woman		man	woman		
18-25	8	3	11	2	-	2	0,18
26-45	105	43	148	51	34	85	0,58
46-55	100	38	138	42	51	93	0,67
56-60	16	6	22	6	3	9	0,41
>60	6	4	10	1	-	1	0,10
Total	235	94	328	102	88	190	0,58

Table III. Structure of radiological diagnosis and collective effective doses for 1998y.

Structure of radiological diagnosis	Number of radiological examinations	Collective effective doses (man.mSv/y)
Ro-graphy: Chest- PA, LAT	48 15 -total 63	5,04
Cervical spine- AP, LAT	48 12 - total 60	42
Lumbar spine- AP, LAT, LSJ	19 2 2 - total 23	29,9
Scull- PA, LAT	20 9 - total 29	20,3
Hand and wrist - AP	15	10,5
Pelvis- AP	5	3,5
Ro-contrast stomach	13	39
KT brain	6	30
Total	214	180,24

The data in Table II show the most number of the patients treated in clinical conditions are between age range 26-45 and 46-55. The number of radiological examinations per capita varied from 0,10 to 0,67, and the mean value was 0,58. The results in Table III for the structure of radiological diagnosis show the most number of radiological examinations are for the chest and cervical spine- 63 and 60 respectively.

For the investigation period (1990-1999) diagnostic medical exposure provides 0,54 mSv/y average dose per patient.

Conclusions

The Bulgarian population exposure, presented as a mean annual effective collective doses, amounts to: 20240 mSv/y from natural background, 6400 mSv/y from X-ray diagnostics; the average effective dose from X-ray diagnostics- 0,34 mSv/y [8]. World- wide, diagnostic medical exposures provide 0,3 mSv/y average dose per capita [9].

The received doses from the patients with occupational pathology are more high than the doses mentioned above. Our results shown the essential of the raising ensure that the medical exposure of patients be the minimum necessary to achieve the required diagnostic objective.

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Exposure of the Bulgarian Population at the Use of Ionising Radiation for Medical Purposes

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As it is in the most of countries, in Bulgaria the usage of ionising radiation for medical purposes - diagnostic examinations and theraupic treatments is the essential source for man-made exposure of the population. Thus, at the end of 20-th century the exposure of population, represented by the average annual effective collective doses, is shown on Table 1.

Table 1. Exposure of the Bulgarian population from different sources at the end of 20-th century. Average annual collective doses, man.Sv/a.

Source of exposure	Background	Medical exposure		Other sources	Total exposure
		Diagnostics	Therapy		
manSv/a, (thousands)	19.4	7.9	1.9	1.6	30.8
% from total exposure (rounded)	63	26	6	5	100

The exposure of the Bulgarian population from natural and man-made sources is object of many studies and publications, some of which have general characteristics [1]. Essential data on this exposure are represented also in the last reports of UNSCEAR-1993 [2] and UNSCEAR-2000 [3]. It is evident from the given data that the medical exposure is equal to about 50% of the background exposure. This value is assess high in comparison with a lot of developed countries from so-called I-st group (Health-care level I), to which Bulgaria belongs also [4]. In the country the creation of a National system for control and management of the medical exposure is forthcoming and it is targeted to effectiveness increase. That means decreasing of the exposure of the population and improvement of the quality and quantity of the useful diagnostic information and also increasing on the quantity and therapeutic effectiveness of the radiotherapy.

X-ray diagnostics.

The Dynamics of the exposure due to X-ray diagnostics is shown in Table 2 (part I). The 5 decades of the second half of the 20-th century are considered and average data on the total number of the population, the number of the examinations per annum, annual frequency, average annual individual effective dose per capita (mSv/a) and relevant average annual collective effective dose (man.Sv/a) are given. Over the last decade (after 1990) a decrease of these

indicators is considered. The reasons are of economic and social-structural origin. In terms of the radiation protection (RP) of the population some problem tasks are delineated:

- ratio of scopic to graphic examination is adverse because of the rise in the cost of the X-ray films;
- considerable part of X-ray apparatuses are old and don't respond to the modern radioprotective requirements;
- supply with new apparatuses like mammographes, CTSc, MRISc is lagging;
- creation of a National system for registration and saving of the information is forthcoming;
- creation of the National system for assurance of the quality of radiation beams is forthcoming;

Nuclear medicine.

The Dynamic of this exposure is shown on Table 2 (part II). The relevant part of the nuclear diagnostic became significant since 1960. During the last decade (after 1990) processes that are typical for the X-ray diagnostics are examined. Reasons are the same. The problems and tasks are analogycal: apparatuses are old; relatively small number of Gamma Cameras; there aren't any PETSc; radiopharmaceuptics are from import; impending creation of a National system for and saving of the information, quality control and quality assurance is forthcoming.

Radiotherapy.

It is known that only just over the last years, the basic quantity of the RP – the effective dose was used also for estimation of the population exposure at radiotherapy [2], [3]. The radiotherapy in Bulgaria has a long story, but at the end of 20-th century it considerably lags by the practice of most of other countries [4]. At present there aren't any accelerators (Linacs, SRS). The annual frequency of the radiotherapy treatments is relatively low. The statistics shows the number of the procedures: teletherapy – 1600; brachytherapy – 4700; radionuclides – 260 or totally 6560 per annum, that gives frequency 0.77 (per 1000 capitas of population). The estimated value of the annual collective effective dose is about 1900 man.Sv/a.

In Bulgaria there is a considerable number of qualified radiologists (94 persons per million capitas). There are also rentgenological and radiological schools with great experience and traditions. The first rate tasks connected with improvement of the RP at the medical use of ionising radiation are outlined as follows:

- considerable improvement in the apparatuses base and use of the modern methods;
- creation of a National system for control and management of medical exposure as well as gradual introduction of the normative decrees of the European Union;
- gradual orientation of thinking of the medical specialists to the priorities connected with the RP of the patients.

RADIATION PROTECTION INFRASTRUCTURE IN THE *REPUBLIC OF CROATIA*

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1. Introduction

According to new legislation of the Republic of Croatia the organizational structure of radiation protection is similar to the organizational structure in many countries of the world. Regulatory (competent) authority for the safe use, traffic, purchase, import and transport of the radioactive sources is the Ministry of Health of the Republic of Croatia.

Ministry of Health of the Republic of Croatia is also responsible for the health of workers who work with radioactive sources in medicine and in industry, aswell for the health of patients and members of public.

Furthermore, Ministry of Health is responsible for the follow-up of radioactivity in the human environment aswell (air, soil, water – sea, lakes, rivers) and, last but not least, radioactive waste management.

To be able to accomplish those tasks, Ministry of Health developed two institutes, Croatian Institute for Radiation Protection and Croatian Institute for Occupational Medicine. For technical assistance and support Ministry of Health has authorise three expert institutions.

Legislation which covers this field is as follows:

1. Sanitary Inspection Act ("Official Gazette" No. 27/99)

2. The Act on the Organization and Responsibilities of Ministries and other Governmental Bodies ("Official Gazette" No. 55/92 and 92/96)

3. Ionizing Radiation Protection Act ("Official Gazette" No. 27/99).

4. The Act on Health Protection ("Official Gazette" No. 75/93, 1/97)

Like in most countries, with the exception of undeveloped countries, the highest number of sources of ionizing radiation which are being used in Croatia is in medicine, over 70%. Most frequent users of those sources in medicine are X-ray departments. But, I would like to stress here that nuclear medicine is the most specific field of use of open radioactive sources, especially regarding radiation protection and decontamination measures and problems.

2. Organisational infrastructure of radiation protection in the Republic of Croatia

1. GOVERNMENT OF THE REPUBLIC OF CROATIA

⇳

2. GOVERNMENTAL RADIATION PROTECTION COMMISSION

⇳

3. *MINISTRY OF HEALTH*

- Department of Sanitary Inspection

- Section for Ionizing and Nonionizing Radiation Protection

⇳ ⇳

4. CROATIAN RADIATION PROTECTION INSTITUTE	**5. CROATIAN INSTITUTE FOR OCCUPATIONAL HEALTH**

6. ⇳ ⇳ ⇳

a) Authorized radiation protection expert institution	b) Authorized radiation protection expert institution	c) Authorized radiation protection expert institution

⇳

7. U S E R S
(Radiation Protection Expert)

Ad 2. Governmental radiation protection commission was established by the Governmental decision ("Official Gazette" No. 16/95). It's role is to be a link between Government and lower institutions. It has 9 members and it's president is minister of health.

Ad 3. Ionizing radiation protection in the Republic of Croatia which is being performed in *Section for Ionizing and Nonionizing Radiation Protection* of the **Department of Sanitary Inspection** of Ministry of Health relates to following procedures:

1. INSPECTION

2. ADMINISTRATIVE MEASURES:

- official decision for improoving measures of radiation protection
- prohibition of work with the radioactive sources to workers whose health surveillance analyses showed abberations
- approvals for trafficking of sources (purchase, use, transport)
- keeping records of all users, sources and workers with radioactive sources

3. ENFORCEMENT (PROSECUTION)

Ad. 4. According to The Act on Health Protection ("Official Gazette" No. 75/93, 1/97) minister of health brought up The decision on establishing Croatian Radiation Protection Institute ("Official Gazette" No. 51/97). This institute is performing all expert works in the field of radiation protection, especially record keeping of all parameters needed to have good radiation protection.

Ad. 5. According to the same Act on Health Protection Government of the Republic of brought up The decision on establishing Croatian Occupational Health Institute ("Official Gazette" No. 10/96). It is not necessary to stress of how big importance for radiation protection is the health protection of workers with radioactive sources.

Health surveillance of workers with radioactive sources is still being performed according to old legislation. Namely, new croatian **Ionizing Radiation Protection Act ("Official Gazette" No. 27/99)** will be in force when it's all regulations will be made and among them is also the one about health surveillance of workers with radioactive sources.

Ministry of Health is improoving every day co-operation with those two institutes. It is of great importance to establish better co-operation of Croatian Occupational Health Institute with the network of 21 authorized units of occupational health throughout Croatia. Next transparency shows those units:

CITY	*OCCUPATIONAL HEALTH UNIT*
1. ***ÈAKOVEC***	2 PRIVATE OCCUPATIONAL HEALTH UNITS
2. ***DUBROVNIK***	PUBLIC HEALTH SERVICE
3. ***KARLOVAC***	PRIVATE OCCUPATIONAL HEALTH UNIT
4. ***KOPRIVNICA***	PUBLIC HEALTH SERVICE
5. ***LABIN***	PRIVATE OCCUPATIONAL HEALTH UNIT
6. ***NAŠICE***	PUBLIC HEALTH SERVICE
7. ***OGULIN***	PRIVATE OCCUPATIONAL HEALTH UNIT
8. ***OSIJEK***	PRIVATE OCCUPATIONAL HEALTH UNIT
9. ***PULA***	PRIVATE OCCUPATIONAL HEALTH UNIT
10. ***RIJEKA***	- PUBLIC HEALTH SERVICE - PRIVATE OCCUPATIONAL HEALTH UNIT
11. ***SLAVONSKI BROD***	PRIVATE OCCUPATIONAL HEALTH UNIT
12. ***SPLIT***	- INSTITUTE FOR PUBLIC HEALTH - PRIVATE OCCUPATIONAL HEALTH UNIT
13. ***ŠIBENIK***	PUBLIC HEALTH SERVICE
14. ***VALPOVO***	PUBLIC HEALTH SERVICE
15. ***VARAŽDIN***	PRIVATE OCCUPATIONAL HEALTH UNIT
16. ***VINKOVCI***	PUBLIC HEALTH SERVICE
17. ***ZADAR***	PUBLIC HEALTH SERVICE
18. ***ZAGREB***	- INSTITUTE FOR MEDICAL RESEARCH AND OCCUPATIONAL HEALTH - INSTITUTE FOR PUBLIC HEALTH OF CITY OF ZAGREB - HEALTH SERVICE OF MINISTRY OF INTERIOR

Ad 6. Authorized radiation protection expert institutions are authorized by special decisions published in "Official Gazette":

1. ***EKOTEH Dosimetry Ltd.*, ("Official Gazette" No. 34/00)**

2. ***INSTITUTE FOR MEDICAL RESEARCH AND OCCUPATIONAL HEALTH*** **("Official Gazette" No. 100/00)**

3. ***"RUĐER BOŠKOVIÆ" INSTITUTE*** **("Official Gazette" No. 10/91)**

They have contracts with users of radioactive sources wich are obligated to perform measures of radiation protection. They make investigations of every source of ionizing radiation in medicine and industry. They also provide dosimetric surveillance of workers with radioactive sources.

Expert institutions must give to the Ministry of Health their report about every investigation of every source they provide and also about their work yearly.

AN OVERVIEW OF
THE IONIZING RADIATION PROTECTION LAW

The Ionizing Radiation Protection Act was adopted by Croatian Parliament in March 1999. It was published in Official Gazzete No. 27/99 on March 19, 1999. and enetred in to force on March 27, 1999. The provisions of the Law were postponed 6 months for preparing 10 regulations with detailed elaboration of some provisions which had to accompany the Law. The Law on september 28, 1999. entered fully into force and regulations which have been prepared are in print and would be issued during 2000.

The Law consists of ten chapters divided into 54 articles with paragraphs: general, provisions, principles of radiation protection, requirements for the practices, exposures, sources, emergencies, radioactive waste, supervision and authorities including the establishment the Croatian Institute for Radiation Protection and the Commission for adiation Protection, penalties for ofences of the provisions, transitional and final provisions.

The basic principles of the Law are the same as in international recommendations (ICRP 60): justification of practices, optimization of protection and safety and limitation of individual doses and are explicitly formulated as the provisions of the Law. According to the Law authorisation for all practices with ionizing radiations is mandatory except for excluded or exempted sources of ionizing radiation. The conditions and procedure for authorization are also formulated in the Law. The principles for exemption are formulated on the basese as defined in the BSS of IAEA.

End user or owner of ionizing radiation sources has primary responsability for implementation of prescribed measures and he has to obtain the authorization for conducting certain practice.

The import of radioactive waste in Republic of Croatia is explicitly forbidden.

Ministry of Health is The Competent Authority for radiation protection in Republic of Croatia. Because of the more effective providing of radiation protection in Croatia pursuant to The Law on Health Care it has been founded The Croatian Institute for Radiation Protection (CRPI) as a medical institute for providing scientific investigations and expertise in the field of radiation protection and for keeping and maintaining records on the sources, users and workers. Also by this Law it is considered that legal persons designated by Minister of Health would perform certain tasks according to special approval if they meet prescribed conditions.

These tasks are:
1. monitoring of the level of exposure and radioactivity in environment,

2. personnel dozimetry service, evaluation of patient exposures and exposure of public
3. assessment of compliance with prescribed regulations of the sources of ionizing radiation prior their commissioning for the purpose of granting the authorization for certain practice,
4. surveillance of working conditions and radiation protection measures related to practices involving sources of ionizing radiations as well as surveillance of contamination and levels of exposure to ionizing radiations of workers,
5. the periodic monitoring of exposure levels at approved intervals and contaminations of objects, rooms and atmosphere inside premises where sources of ionizing radiation are being operated
6. radioactive waste management,
7. occasional checking of the suitability of the measuring instruments and protective devices
8. and other tasks according to approval.

Supervision and enforcement of the safety measures provide the sanitary inspection department of Ministry of Health pursuant to The Law on Sanitary Inspection and according to this Law.

Minister of Health has to bring 10 regulations for detailed elaborations of the various provisions stipulated by the Law which has to ease the implementations of the Law. These are:

1. Regulations on the exposure limits, on the conditions of exposure for special purposes and on the intervention levels;
2. Regulations on the conditions and measures for the ionizing radiation protection for conducting practices involving x-ray units, accelerators and other devices generating ionizing radiation;
3. Regulations on the conditions and measures for the ionizing radiation protection for conducting practices involving radioactive substances;
4. Regulations on the conditions and ways of obtaining the professional skills as a precondition for work with the sources of ionizing radiation;
5. Regulations on the health conditions, criteria, content, methods and intervals of maintaining of the records about health surveillance of persons who work with sources of ionizing radiation;
6. Regulations on radioactive waste management;
7. Regulations on the conditions, methods, premises and intervals of systematic environmental radiological monitoring;
8. Regulations on the patients ionizing radiation protection in medicine and stomatology;
9. Regulations on the methods and intervals of the surveillance of the sources of ionizing radiations, personnel monitoring, monitoring of exposure of the patients, on maintaining records and registars and on reporting;
10. Regulations on the conditions for authorization of legal persons to provide specific expert duties in the field of ionizing radiation protection.

The Goverment of Republic of Croatia is authorised to bring: "The National Plan and Programme of Ionizing Radiation Protection in the Case of Emergency" which has to elaborate systematically whole infrastructure to meet any accidental case involving radioactive sources and nuclear accident as well.

The nuclear safety issues are out of the scope of this law.

RADIOLOGICAL PROTECTION IN MEDICINE: CURRENT PROBLEMS IN INDONESIA

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ABSTRACT

Radiological Protection in Medicine: Current Problems in Indonesia. The medical applications of ionizing radiation in Indonesia have been introduced in the early 20th century. Since then it dominates the application of radiation in various fields. By several regulations, the government has tried to control these applications. However, some problems are still persisting. This paper presents the safety-related regulations that in place in Indonesia, authorization status regarding medical applications, the existing problems and the eforts to tackle them. Eventhough the funds are always the scapegoat, it is believed that the real reason for all problems concerning radiation protection in Indonesia is lack of safety culture among the users.

INTRODUCTION

A German-born Dutch physician introduced the first use of atomic energy in Indonesia in the early 20th century. During the first five decades, the peaceful uses of atomic energy in this country had been dominated by x-ray radiation for medical purposes, both diagnostic and therapy. In the 1960s, this was followed gradually by the use in research and agriculture. The last two decades saw the rapid growth of these uses, including in industry, research, agriculture, and education, as well as in hospitals.

Despite its rapid growth in various aspects, the potential hazard of the use of atomic energy has also been realized from the very beginning. As a matter of fact, activities in radiation safety in Indonesia have been initiated as early as in the middle of 1950s. In recognizing the need to carry out research on the effect of radiation on man in the light of the bombing of Hiroshima and Nagasaki with atomic weapon, the government at that time established the Committee for Study on Radioactivity.

The highest regulations concerning the execution of the use and control of nuclear energy in Indonesia at present is Act No. 10 Year 1997 on Nuclear Energy. This Act supersedes the Basic Stipulations of Atomic Energy Act of 1964 which was then found to be inappropriate due to the development in times and continuing progress in science and technology in the use of nuclear energy.

Article 16 of the 1997 Act states that any activity related to the utilisation of nuclear energy shall maintain the safety, security, peace, health of the workers and the public, and protection of the environment. According to this article, therefore, the safety provisions need to be further regulated, including the provision for radiological protection in medicine.

The new Act also separates the authority in executing and controlling of nuclear energy into two different institutions to avoid the overlapping of activities on the use and

control, as well as to optimise the control of nuclear energy in order to improve nuclear safety. The function of execution is given to an executing body, which is called the National Nuclear Energy Agency (BATAN), whereas the function of control is given to a regulatory body called the Nuclear Energy Control Board (BAPETEN).

REGULATION

In the regulation system in Indonesia, the government regulation has the second power after the Act. To implement article 16 of the 1997 Act No. 10 of Nuclear Energy, Government Regulation No. 63 Year 2000 has been enacted. This regulation, which stipulates the safety and health against the utilisation of ionizing radiation, replaces Government Regulation No. 11 Year 1975 on the Working Safety Provisions against Radiation.

The scope of the government regulation No. 63 Year 2000 includes the requirements for dose limitation system, radiation safety management system, calibration, preparedness and countermeasures for radiological accident. In the radiation safety management system, the owner shall apply and establish radiation protection organization, radioactivity and radiation dose monitoring, radiation protection instrument, health examination of workers, document record keeping, quality assurance and education and training.

Concerning the radiological protection for patient, article 6 of the regulation states that "in applying doses for diagnostic and therapeutic medical purposes, the owner shall consider the patient protection against ionizing radiation pursuant to article 3 item (a) and (c)". Article 3 itself states that "(a) any utilisation of nuclear energy shall produces benefit to offset the radiation harm that it might cause, (b) the radiation dose received by workers or member of the public shall not exceed the dose limit specified by the regulatory authority, and (c) any utilisation of nuclear energy shall be designed and radiation sources shall be designed and operated so that the magnitude of radiation exposures be kept as low as reasonably achievable".

Concerning calibration, article 30 clause (1) and (2) of the regulation states that "the owner shall calibrate its radiation survey instrument regularly at least once a year" and "the owner shall calibrate its radiotherapy machine output regularly at least once in two years". Further guidance has been enacted in 1991 by BATAN before BAPETEN was established. Director General of BATAN Decree No. 84 Year 1991 regulates the responsibility of the owner concerning calibration and radionuclide standardization, level and responsibility of calibration facility, and certification and tag of calibration and standardization. This decree will soon be revised by BAPETEN.

AUTHORIZATION STATUS

The authorization system in Indonesia is applying only the licensing scheme. By this scheme, all legal person utilising nuclear energy shall apply for license from the regulatory authority. The license will be granted if the person meet five requirements, mostly related to safety, stipulated in Government Regulation No. 64 Year 2000 on the Licensing for Utilisation of Nuclear Energy. This new regulation replaces the old one stipulated in 1975 (i.e., Government Regulation No. 12 Year 1975 on the Licensing of Radioactive Materials).

In the field of medical, by the end of December 1999 there were 1307 licenses have been granted. These consist of 40 licenses for therapy application (8 linear accelerators, 28 radioisotopes and 14 X-ray machine), 12 for diagnostic application with radioisotopes, 1197 for diagnostic X-rays, and 58 for storage of radioisotopes.

The application of radiation in the field of medical is in fact the highest among other fields. By the end of December 1999, the licenses granted to all other application were 464, consists of 234 licenses for radiography, 82 for gauging, 21 for logging, 26 for chemical analysis and 101 for various others.

THE PROBLEMS

Problems encountered in radiological protection in the medical application of radiation in Indonesia can be categorised as administrative-related and technical-related. From administrative point of view, as much as 905 licenses for hospitals have been expired by the end of January 1999. In the same time, calibration certificates for output of 19 therapy units have also expired and 11 therapy units were operated without license. In addition, calibration certificates for radiation survey instrument in most hospitals were expired as well, and even some hospitals have no instrument at all.

From technical viewpoint, inspection conducted during 1999 to some hospitals in four provinces revealed that most hospitals have no logbook on the therapeutic irradiation for patient. In addition, record keeping of occupational doses was not maintained and there were no health examination carried out for the workers.

EFFORTS TO TACKLE THE PROBLEMS

Before BAPETEN was established, control of utilisation of nuclear energy in Indonesia was carried out by BATAN. BATAN and Department of Health were actually set up a Joint Commission in 1991 to tackle the problems encountered in the medical applications of radiation. Every year this commission gave recommendations to hospitals concerning radiation control. The Directorate General of Medical Services of the Department of Health has regularly also released memorandum to hospitals concerning radiological safety. However, all these recommendations made by the Joint Commission, as well as memorandum from the Department of Health, were ignored by most hospitals. The ignorance was thought to be rooted from behaviour, responsibility, communication and administrative bureaucracy.

In order to tackle the above-mentioned problems, several efforts have been conducting by the BAPETEN since the middle of 1999. Persuasive approach was started with the hospitals by letters and dialogue, rather with punishment as stipulated in the 1997 Act. This approach was quite successful, since some the hospitals beginning to realize the importance of license and then extended their licenses.

Recently the controlling part of joint commission of BATAN-Department of Health was updated and become an MoU between BAPETEN and Department of Health on building and controlling nuclear energy in the field of medicine. This new joint commission will focus their tasks on calibration of various radiation instruments used in hospitals and other medical institutions, as well as on other safety-related problems.

BAPETEN is at present also developing some safety-related guidance to various applications. Two of them that related to radiological protection in medicine are guidance

on dose levels for diagnostic radiology for patient and guidance on safety standards for the application of radiotherapy instrument. These guidances are still in preparation and planned to be ready by the beginning of next year.

The data from Department of Health also revealed that all over Indonesia there are only five radiophysicists, or medical physicists, in duty in hospitals. These medical physicists were not the real ones, since they are actually radiographers that trained specifically in medical physics after working for more than 10 years.

To cope with the lack of medical physicists, Physics Department of the University of Indonesia, in collaboration with Faculty of Medicine, BATAN and Department of Health, since 1998 have been running interest on medical physics. Students must pass 105 credits on physics before voluntarily choosing medical physics. Number of credits to finish study on physics are 144, so that subjects related to medical physics to be passed are 39.

In spite of several actions carried out by BAPETEN, some problems are still persisting. In the calibration of output therapy machine, for example, the one who pay the cost actually government, not the hospitals themselves. When BAPETEN asked the hospitals why they did not calibrate their output machine, they just simply said that they have no money for it. BAPETEN was then asked for extra budget to the government, which luckily agreed, to perform this calibration. What will happen in two years time, when the hospitals need to recalibrate their output and the government has no more money?

Fund is also the reason why radiation workers in some big government hospitals are not personally monitored. To make it worse the situation, facility within the Department of Health that gives personal radiation monitoring services is also facing the same problem, not enough funds to monitor all radiation workers in government hospitals.

A medical physicist is known to be needed by hospitals. However, hospitals in Indonesia are still not interested to recruit medical physicist. The tasks of physicists at present are handled by radiographers. The medical physicist who will soon graduate are still not certain whether they can work at hospitals, since it is still not compulsory for the hospitals to recruit medical physicist to perform the physics-related tasks in hospitals.

CONCLUDING REMARKS

The problems in radiological protection in medicine in Indonesia are quite complicated. Fund is always the scapegoat for the problems, but it is believed that it is not the real reason. The main reason is thought to be caused by the lack of behaviour and responsibility toward safety, or in short safety culture, among the users, as well as communication between parties involved in the radiation safety and the existing administrative bureaucracy . The government, particularly BAPETEN as the regulatory authority, therefore, shall continuously promoting safety culture and communication to achieve the highest standard in safety among the users of radiation in Indonesia.

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PALLIATIVE RADIATION THERAPY FOR OVERLOADING RADIOTHERAPY CENTRE, ESPECIALLY FOR DEVELOPING COUNTRY.

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Abstract:

In developing country, most of the cancer cases are diagnosed in the advanced stages. So, the palliative radiation therapy is the only choice of therapy for these inoperable cases where the chemotherapy is not effective or afforded. In conventional radiation therapy, daily dose of 200 cGy for total 4000 cGy in more than 20 days (sometimes, up to 6000 cGy) is used. By using Linear-quadratic model theory of cell killing by radiation, it can be calculated early and late effects by using alpha and beta ratio. This theory is still the best for radiation cell killing until the new detail one is discovered. These data are obtained by experimental as well as clinical results. The effective radiation dose can be calculated by using the data to different organs which if involved in the radiation fields. This can change the daily dose to palliative cases in which the late effect is unnecessary. The daily doses can be 300, 400, 500, and sometimes 1000 cGy per single fraction. These modalities are well documented. It is recommend to change the short term high-dose palliative radiation therapy instead of using conventional palliative radiation therapy in overloading radiotherapy centre, especially for developing country. The reasons are mainly radiation protection aspect, not only for the patients and those who involved with the radiation therapy but also to reduce the unnecessary radiation exposure to the environment.

Introduction:

Ideally, a teletherapy machine can usually treat about 40 patients a day, each patient taking about 15 minutes. [1]

In the developing countries, very few teletherapy machines have to treat a large number of patients. For example, Myanmar has three radiotherapy centres and the largest is Yangon General Hospital (YGH). YGH has two functioning teletherapy machines, both cobalt 60 machines. Each machine must treat 120±20 patients a day, each patient taking less than 11 minutes. As principle, radiotherapy treatments are curative and palliative. Curative radiation treatment is 200 cGy per day for 6000 to 6600 cGy, conventionally. Sometimes, 7000 to 8000 cGy depends on the radiation field size and anatomical location[2]. Palliative radiation treatment is conventionally 200 cGy per day for 4000 cGy. The short term treatment, for example, contains 300 cGy for 10 fractions, 400 cGy for 5 fractions, 500 cGy for 4 fractions or sometime with preradiation medication 1000 cGy for single fraction especially in the pelvic area[3].

By using Linear-quadratic model theory of cell killing by radiation, it can be calculated early and late effects by using alpha and beta ratio[4]. This theory is still the best for radiation cell killing until the new detail one is discovered. These data are obtained by experimental as well as clinical results[5]. The effective radiation dose can be calculated by using the data to different organs which if involved in the radiation fields. This can change the daily dose to palliative cases in which the late effect is unnecessary.

Method:

Linear-quadratic model theory of radiation cell killing composes surviving fraction radiation dose are related linearly and quadratically.[4]

$S = e\ (-aD - bD^2)$

In this equation, S is the fraction of cells surviving a dose D, and a and b are constants.

$aD = bD^2$, or $D = a/b$

There are two components of cell killing: one is proportional to dose (aD), while the other is proportional to the square of the dose (bD^2). The dose at which the linear and quadratic components are equal is the ratio a/b.

The deriving formula is biological effective dose (BED).

$BED = D\ (1+d/(\alpha/b))$ dose in Gy.

D is total dose and number of fractions(n) multiples to daily dose (d).

$D = nd$

Alpha-beta ratio is roughly 10 for acute reaction tissue and tumour tissue, 3 for late responding tissue. The detail data varies with different experiments, different organs and clinical observations. By using this formula, BED is calculated for short term palliation for pelvic diseases. The results are as follow.

Results:

By using BED formula and alpha-beta ration the following doses obtained,

$BED = 40\ (1+2/10) = 48$ Gy

$BED = 30\ (1+3/10) = 39$ Gy

$BED = 20\ (1+4/10) = 28$ Gy

$BED = 20\ (1+5/10) = 30$ Gy

$BED = 10\ (1+10/10) = 20$ Gy

If 40 Gy with 2 Gy per fraction the BED = 48 Gy is normalised, the total fractions for 3 Gy per fraction with BED 48 Gy can be calculated as following;

$D = BED/\ (1+d/10) = 48/(1+3/10) = 36.9$ Gy, approximately 12 fractions

For 4 Gy per fraction;

$D = BED/\ (1+d/10) = 48/(1+4/10) = 34.2$ Gy, approximately 8 fractions

For 5 Gy per fraction;

$D = BED/\ (1+d/10) = 48/(1+5/10) = 32$ Gy, approximately 6 fractions

For 10 Gy per fraction;,

$D = BED/\ (1+d/10) = 48/(1+10/10) = 24$ Gy, approximately 2 fractions

Discussions:

By using the linear-quadratic model and BED equation, the total fractions are higher than the conventional fractions. To get the effective palliative to the patients by daily high dose fractionation, it should give more fractions than the conventional fractions with same dose per fraction. On the other hand, the field size, the field site and organs at risk, and interval between fractions are very important factors to be considered for short term palliative radiation. To give short term high-dose palliative radiation therapy, radiation oncologist

should consider not only biological effective dose based on linear-quadratic model but also his cleaver clinical judgement.

Conclusion:

It is recommend to change the short term high-dose palliative radiation therapy instead of using conventional palliative radiation therapy in overloading radiotherapy centre, especially for developing country. The reasons are mainly radiation protection aspect, not only for the patients and those who involved with the radiation therapy but also to reduce the unnecessary radiation exposure to the environment.

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Patient's and Occupational Dose Exposure in Roentgen Examinations

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ABSTRACT

The study of roentgen exposure in diagnostic, is a constant obligation everywhere because:

a. the higher number of people undergoing roentgen examination and
b. relative high exposure doses during examinations.

We are interested about exposure doses for patients and occupational staff only.
Nevertheless, being linked with the main goal of our paper; **"exposure dose"** we would give below the figures of frequencies for widely performed examinations, just to calculate such parameters like mean exposure dose and collective effective dose.
The use of ionizing radiation in Albania is as follow: about 70% belong to the medical application and 30% to the others, research, agriculture and industrial applications.
From the medicine uses 80% belong to the X-rays and 20% radioactive sources. The use of X-ray procedure in medicine is 85% in diagnostic and 15% in radiotherapy.
In this way, the main field, which contribute of exposure doses for both, population and occupational staff in Albania, is X-ray diagnostic irradiation. The amount of exposure dose as well as the collective dose coming up from X-ray in diagnostic is about 80% of total value for above-mentioned parameters.

INTRODUCTION

The evaluations of exposure dose are given separately for patients and occupational staff. From these values of exposure dose, we tried an approach, through extrapolation for total exposure dose coming up from all X-ray diagnostic examinations. For such evaluation (of patient doses) we use the data carried out during 80-th in vitro and in vivo with TLD-s, as well as the data performed with PMX-meter and Harshaw TLD-s.
We have discussed about most widely used examinations as: chest and stomach fluoroscopic procedures, skeleton and head & neck radiographs, which have the frequencies of 307, 20, 140, and 50 exposure/ year/ 1000 inhabitants respectively.
The justification and optimization principles as the main principles in radiation protection field have been in our consideration during X-ray examinations. The number of diagnostic X-ray examinations in Albania has not increased significantly in recent years.
UNSCEAR (United Nations Scientific Committee on the effects of atomic Radiation) recommends regular surveys of the number of X-ray examinations in order to study the trends and differences in the use of radiation between different countries. Changes in the distribution of X-ray examinations contribute to changes in the collective dose of the population.

MATERIAL and METHODS

Actually, the individual monitoring (workers + patients) has been performed, during our study with TLD-100 cards, given by IAEA, which control was established already.
Every month, the Personal Dosimetry Division in Institute of Nuclear Physics (INP) distributes about 300 pieces of TLD-100 cards to measure the effective dose of the nuclear facilities in Tirana city. We are tried to extents the personnel, patients and population control by TLD-s cards in some other cities of Albania, for instance in Durres, Korça, Shkodra cities.
In table Ia and Ib are shown the figures for frequencies of above-mentioned examinations for both **a** (in vitro) and **b** (in vivo) examinations during period of our study.

G R A P H I E S					Fluorosco pies	
S k e l e t o n						
Head & Neck	**Chest**	**Abdomen**	**Pelvis**	**Extremities**	**Chest**	**Stomach**
50	60	10	20	50	307	20

Table Ia. Frequency / 1000 inhabitants/ year **in vitro** examinations

On measuring of exposure doses, we performed mainly in vivo measurements. For these measurements we have used the Harshaw TLD-s. For each type of examination we perform at least 8 sets of measurements, and for each set we have used 10-15 TLD-s.

G R A P H I E S					Fluorosco pies	
S k e l e t o n						
Head & Neck	**Chest**	**Abdomen**	**Pelvis**	**Extremities**	**Chest**	**Stomach**
42	45	10	17	52	280	15

Table Ib. Frequency / 1000 inhabitants/ year **in vivo** examinations

The most significant contribution to the radiation dose to population is mainly due to **in vivo** examinations. While results in table Ic shown the figure of the mean annual effective dose for occupational staff of Tirana city during 1997,1998,1999 years.

No.	**Occupational Practices**	Mean Annual Effective Doses (mSv)		
		1997	**1998**	**1999**
1	Hospital No. 1	3.45	3.50	2.95
2	Ptisio-Pneumology Hospital	3.40	3.90	4.30
3	Dispensary anti TBS	4.60	4.55	4.45
4	Nuclear Medicine	3.39	4.65	4.20
5	Regional Polyclinic No.2	4.65	4.80	4.85

Table Ic. Mean Annual Effective dose of Occupational Staff in Tirana City

So, for instance to keep the exposure dose for chest fluoroscopy, we have measured in 10 different patients, and to each patient we put on the skin surface of chest size 15 TLD-s, as well as about 10 TLD-s in other points outside of chest size, like gonads, eyes etc.
A set of output X-ray beam's tube, without patient, at the same conditions (Kv; mAs; source-skin-distance; beam aperture) were performed with ionizing chamber to verify the exposure doses measured by TLD-s.
The last one were carried out with universal dosimeter + ionizing chamber of appropriate volume, HVL etc.
In table 2a is show an example of output verification for a beam used in chest fluoroscopy (85Kv; 1.3 mA).

Exposure time (sec)	15	10	18	30	20	24	30	20
Measure by TLD (mGy)	9.5	8	10	17.2	15	19.3	22.1	14
Tube output values mAs	0.48	0.61	0.42	0.44	0.58	0.61	0.54	0.52
Measure by ionizing chamber (mGy	11.5	9.4	14.2	23.7	15.7	18.9	23.2	15.7
Tube output measured ionizing chamber mAs	0.59	0.72	0.61	0.61	0.60	0.60	0.62	0.61

Table 2a Output verification for beam in chest fluoroscopy

The figures in third and fifth rows, represents the tube output values (mAs), while in the last column are shown the mean values of each one set. The difference of those in percentage is about 11%; which is a good agreement between two sets.
The exposure doses, in average values, calculated for 8-15 examination of each type are shown in table 2b.

Methods	G R A P H I E S					Fluoroso pies	
	S k e l e t o n						
	Head & Neck	**Chest**	**Abdomen**	**Pelvis**	**Extremities**	**Chest**	**Stomach**
TLD-s	140 (15)	50 (15)	650 (10)	820 (12)	20 (15)	112 (20)	200 (9)
Ionizing Chamber	60 (15)	52 (12)	500 (10)	900 (12)	30 (15)	136 (20)	300 (9)

Table 2b The values of exposure doses for different examinations (mRem).

The figures in brackets showed the number of measurements for a given type of examination. The set b of measurements was carried out **in vivo** for different examinations with Harshaw TLD-s and parallel with TLD furnished by EC. Furthermore were done directly the measurements of different beam's output with PMX-meter.

The agreement between both sets **a (in vitro)** and **b (in vivo)** of measurements is quite good within the limits of fluctuation down by the differences of parameters used for the same type of examinations in different X-ray machines. In table 2c are shown the average values of beam output per 1mAs for different X-ray machines and different types of examinations.

Methods	Graphies (Skeleton)			Fluorosco pies	
	Chest + Abdomen	Abdomen + Pelvis	Head + Neck	Chest	Stomach
TLD-s	60	100	80	65	95
Beam output	70	105	77	70	100

Table 2c Average values of beams output in mRem / 1 mAs

RESULTS

The main goal of our study is to calculate the mean exposure dose per capita-year of population. Our results are extrapolate to whole population because:

A] The frequency of X-ray diagnostic exposure for above-mentioned examinations is high (the average value of Ia and Ib figures is about 500 examinations / 1000 inhabitants year and adding to this value those of other types of examinations, not included in our paper, the frequency will be more than 750 for patient examination. It means that the "Patient Group" is almost equal with "Whole Population-Group".

B] Taking into account, the spread out, of many X-ray biologic damages from patients to others, we need to have common average level of irradiation for whole population, where in this case are included and occupational staff, who are working in ionizing radiation field too.

So, from the point of view of common average level in table 3,represents the average values for each type of examination carried out from tables 2a ; 2b as well as from all TLD-s measurements.

	G R A P H I E S				Fluorosco pies	
	S k e l e t o n					
	Head + Neck	**Chest**	**Abdomen**	**Pelvis**	**Chest**	**Stomach**
Average value of exposure dose	193	53	612	800	227	464
Frequency	51	46	53	10	294	18
Exposure dose/capita	3.8	1.15	11.55	80	0.8	25.8

Table3 The average values of exposure dose for different examination (mRem)

The annual exposure dose per capita, given from patients examinations is about 62.64 mRem (0.6264 mGy) and about 0.5123 mGy for occupational staff.

DISCUSSIONS

The ESTRO-EQUAL quality audits for radiotherapy : results 1998-2000.

On behalf of the EQUAL Committee,
ESTRO office, Brussels, Belgium

An ESTRO (European Society for Therapeutic Radiology and Oncology) Quality Assurance Network for radiotherapy (EQUAL) has been set up for 24 European countries. The network deals with measurements performed with mailed TLD irradiated in reference and non-reference conditions, for on-axis points in photon and electron beams. For the photon beams, the checks include the reference beam output, the beam output variation with collimator opening, the depth dose data and the wedge transmission factors. For electron beams, the reference beam output is checked for three different field sizes.
The LiF DTL937 (Philitech, France) is used and read with the PCL3 automatic reader (FIMEL-PTW). The participating centres irradiate the TLD capsules to an absorbed dose of 2 Gy estimated with the Treatment Planning System used in clinical routine.
Photon beams results : Between 1998-2000, the EQUAL measuring laboratory has checked **282 out of 394 accepted centres** including 757 beams, 13% of ^{60}Co beams and 87% of X-ray beams. The results show that 2% of the beam output in reference conditions and 3% of the percentage depth doses are outside the tolerance level (deviation >±5%) (excluding deviations observed in the 1st check and attributed to errors in irradiation and set-up). The standard deviation for the beam output is 2.1%. 4% of the beam output variations with collimator opening and also 4% of the wedge transmission factors show deviations >±5%. The global results analysis shows deviations >±5% in at least 1 point for 133 out of the 757 beams, mainly for large and rectangular fields and for wedged beams. 45 rechecked beams out of 133 present one "real dosimetric" problem in one or more parameters, corresponding to 7% of the 669 beams
Electron beams results : From November 1999 to end of July 2000, the EQUAL has checked 81 centres with 228 beams, 83 low-energy beams (≤ 10 MeV) (36%) and 145 high-energy beams (> 10 MeV) (64%). The results show that 1.5% of the beam output in reference conditions (10 cm x 10 cm) and about 2.5 to 3% of the beam output for the other field sizes (15 cm x 20 cm and 7 cm x 7 cm) are outside the tolerance level (deviation >±5%). The standard deviation for the beam output in reference conditions (10 cm x 10 cm) is 2.1% and 2.5% for the beam output for the other field sizes. In addition, the percentage of deviations > ±3% and ≤ ±5% observed on the reference beam output is twice higher for the checked electron beams than for the photon beams.
Conclusions : Generally, there is a high accuracy in the reference-geometry dosimetry in Europe, but **larger deviations are more frequent in non-standard irradiation geometries**. The EQUAL programme has proven to be an essential part of the quality audit of radiotherapy.

Keywords: Radiotherapy, Quality Assurance network, Dosimetry intercomparisons, TLD

STAFF DOSIMETRY AND RISK ASSESSMENT DURING DIGESTIVE AND ANGIOGRAPHIC EXAMINATIONS

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Abstract
The use of ionizing radiation in medical applications involves not only a risk for the patient, but also for the staff which executed the related examinations. The dose to the forehead, neck, fingers and wrist of a radiologist and an assisting nurse were measured with thermoluminescent dosimeters during angiographic and digestive examinations respectively. Dose to eye lenses and effective dose were estimated for a working period of one year. Effective doses were under the established limit of 20 mSv per year. Nurse eye lens dose was higher than the limit of 150 mSv. Differences of a factor of 3.8 were observed between nurse and radiologist doses. Angiographic procedures are considered as high risk examinations, however, digestive examinations can have a higher risk than interventional procedures.

1. Introduction

The use of ionising radiation in the imaging of body tissues for diagnostic and therapeutic purposes, involves not only a risk for the patient, but also for the staff which executes the related examinations. These risks can be stochastic or deterministic, and may appear minutes or years after the irradiation. Some examples of these radiation-related effects in x-ray workers are: skin cancer, an elevated incidence of leukaemia in radiologists, and radiation cataractogenesis [1]. In the following study, the dose to the forehead, neck, fingers and wrist of both radiologist and assisting nurses have been measured during angiographic and digestive x-ray examinations. From the data collected, the dose to the lens of the eye and the effective dose have been estimated for a working period of one year. Results have been compared with established limits for workers [2]. The related risks have been evaluated in order to establish adequate safety measures.

2. Materials and methods

The angiographic examinations were carried out in a digital x-ray unit Siemens Multiskop equipped with C-arm undercouch tube, high frequency generator, digital processing system and carbon fiber table. No bucky is present in the equipment. All of the examinations but one where executed in the same operation mode: fluoroscopy mode "normal", dose level "normal" (500), 3 frames per second. The dose level "low" (200) was used for the blood sampling of the parathyroid glands.
The digestive examinations were executed in a General Electric Prestilix 1600X DRS unit equipped with overcouch tube and high frequency generator. Both digital and conventional radiographic techniques were used.
The entrance surface dose (ESD) at different positions of the body was measured with thermoluminescent dosimeters TLD 100-H (LiF: Mg, Cu, P; Harshaw Solon). A black polyethylene sachet containing one dosimeter was placed on the forehead and neck (on the thyroid collar, at the external surface) of the radiographer and the assisting nurse. For the assisting nurse the dose to the fingers and the wrist(right hand) was also measured. For the fingers, a plastic ring was used to hold the sachet. The TLD chips were calibrated in-air with a Siemens x-ray unit equipped with lost tube and high frequency generator . The tube potentials selected were 70 kVp for the angiographic procedures, and 81 kVp for the digestive examinations. The chips were read in an automatic Harshaw 5500 reader and annealed in a PTW-TLDO oven. The precision of the group of dosimeters was 6% at 11.4 mGy. The individual sensitivities did not differ by more than 17% from the mean sensitivity of the whole group of dosimeters.
The effective dose was estimated conservatively from the measured doses at the forehead and at the neck (over thyroid collar) using conversion coefficients calculated by Faulkner [3]. These

coefficients depend on the position of the x-ray tube with respect to the table, the energy of the beam, and the position of the dosimeter in the body.

3. Results and discussion

The mean number of exams per day carried out by both radiologist (4 exams) and assisting nurse (3.5 exams) were determined to estimate effective dose and eye lens dose for a working period of one year (840 exams radiologist, 735 exams nurse).
The measured values of ESD to forehead and neck are given in Table I (radiologist) and Table II (nurse). Fluoroscopy time and number of frames per type of examination are also given. The values of effective dose and dose to the lens of the eye are shown in Figure 1 and 2. The mean values were determined from the mean dose per examination calculated from all of the examinations. Minimum and maximum values were determined from the minimum and maximum doses per type of examination, from the type of examinations with the lowest and highest mean doses.
In Table III the results of the measurements of dose at fingers and wrist levels of the assisting nurse are summarised.

Table I. Doses at forehead and at neck (over thyroid collar) of a radiologist executing interventional procedures. The number of examinations executed is given between brackets.

examination type		fluoro time (sec)	# frames	dose forehead (mGy)	dose neck (mGy)
AC-IM (9)	min - max	156 - 288	150 - 459	0.06 – 0.13	0.10 – 0.31
	mean ± stdev	197	262	0.10 ± 0.03	0.19 ± 0.07
AC-HNV (12)		78 - 564	99 - 278	0.03 – 0.09	0.04 – 0.14
	mean ± stdev	314	188	0.06 ± 0.02	0.09 ± 0.03
Angioplasty (2)	min - max	492 - 522	55 - 88	0.04 – 0.05	0.10 – 0.18
	mean ± stdev	507	72	0.04 ± 0.01	0.14 ± 0.05
CT-AMS (3)	min - max	162 - 204	225 - 390	0.11 – 0.15	0.28 – 0.40
	mean ± stdev	183	320	0.12 ± 0.02	0.35 ± 0.06
diverse (11)	min - max	108 - 2286	87 - 508	0.02 – 0.27	0.03 – 0.33
	mean ± stdev	468	257	0.05 ± 0.04	0.11 ± 0.09
total (37)	min - max	78 - 2286	55 - 508	0.02 – 0.27	0.03 – 0.40
	mean ± stdev	407	247	0.08 ± 0.05	0.16 ± 0.1

AC-IM: aortic cross-inferior members; AC-HNV: aortic cross-head and neck vases; CT-ASM: coeliaque trunk- mesantic superior artery, min: minimum; max: maximum; stdev: standard deviation.

Table VI. Measured doses at the forehead of an assisting nurse executing digestive examinations. The number of examinations executed is given between brackets.

examination type		fluoro time (sec)	# frames	dose forehead (mGy)
barium enema double contrast (14)	min - max	[b]	12 - 15	0.25 - 0.79
	mean ± stdev	403	14	0.50 ± 0.1
barium meal (5)	min - max	[b]	33 - 63	0.24 - 0.85
	mean ± stdev	321	51	0.43 ± 0.3
swallow (4)	min - max	[b]	41 - 66	0.05 - 0.24
	mean ± stdev	46	57	0.15 ± 0.1
small bowel study via	min - max	[b]	37 - 70	0.11 - 0.42
nasoduodenal administration (10)	mean	1045	53	0.25
barium enema single contrast (4)	min - max	[b]	8 - 14	0.15 - 0.23
	mean ± stdev	246	11	0.19 ± 0.04
oesophagus (1)	min - max	[b]	18 - 53	[a]
	mean	134	40	0.15
defaecography (1)	min - max	[b]	30 - 50	[a]
	mean	87	40	0.23

small bowel study via oral	min - max	[b]	19 - 40	[a]
administration (1)	mean	553	36	0.23
fistulography (1)	min - max	[b]	9 - 17	[a]
	mean	113	13	0.11
all examinations (41)	min - max	[b]	8 - 70	0.11 - 0.85
	mean ± stdev	328	35	0.34 ±0.2

[a] not applicable, [b] values not given, min: minimum; max: maximum; stdev: standard deviation.

Table III. Measured values of entrance surface dose (ESD), and calculated values of absorbed dose at fingers and wrist (extrapolated for one year period)of an assisting nurse in digestive examinations.

	ESD at fingers mGy	ESD at wrist mGy	absorbed dose fingers (one year period) mSv	absorbed dose wrist (one year period) mSv
minimum	0.07	0.08	55.4	63.3
maximum	0.50	0.68	395.4	537.8
mean ± stdev.	0.26 ± 0.2	0.32 ± 0.2	206.8	255.3

stdev, standard deviation.

3. Summary of conclusions

Differences of a factor of 3.9 for the dose to the lens of the eye, and 3.7 for the effective dose were observed between assisting nurse and radiologist (the latest with the lowest doses).

Mean effective dose for both radiologist and nurse was under the limit of 20 mSv per year [4]. Mean and maximum radiologist eye doses were under the limit of 150 mSv per year [4]. However, the nurse eye lens doses were higher than the established limit (Figure 1). The risk involved is the formation of cataracts, which is a late deterministic effect (symptoms appear many years after the irradiation). The mean dose to fingers and wrist estimated for one year were under the limit of 500 mSv for skin.

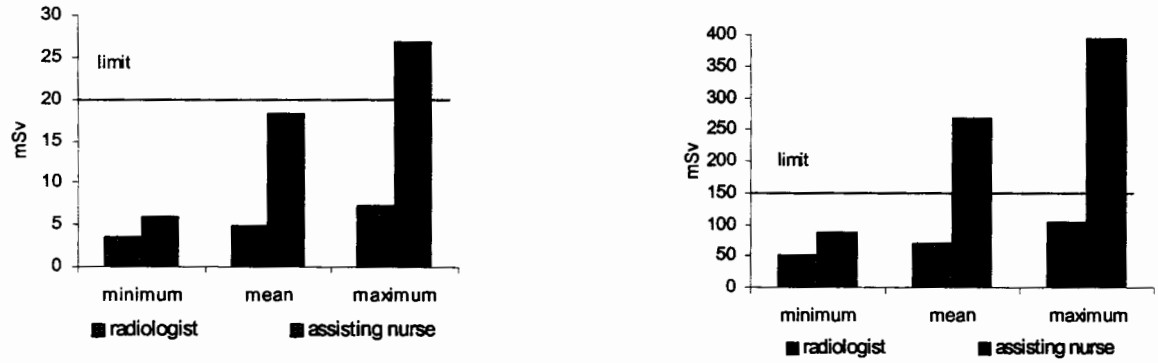
To analyse the differences between effective dose estimated from doses at the forehead and at the neck level, the relation between the ED forehead and ED neck was plotted in a graphic (Figure 2). It can be observed that, with the exception of TC-MS and angioplasty procedures, differences up to a factor of 4 exist for the different examinations. This suggests the use of two dosimeters in lieu of one for the estimation of effective dose of personnel executing high-risk examinations [4,5,6]. Both the NCRP and the ICRP recommend the use of two dosimeters for the monitoring of workers wearing a protective apron: one over and one under the apron. The interpretation of the combined results is dependent on the local irradiation conditions and any regulatory requirements [7-8]. They also recommend that if only one dosimeter is used, it should be worn over the apron, high on the trunk. The result will overestimate the effective dose, but will provide information on the dose to the skin, eye, and unshielded parts of the body.

Angiographic procedures are considered a type of radiological examinations with the highest risk for both patient and staff members (especially the radiologist executing the procedures). However, it has been observed that digestive examinations can have a higher risk than interventional examinations, when inadequate equipment and protocols are used (long fluoroscopy times, large number of frames, overcouch tube). It is not customary for the staff to wear protective lead glasses or thyroid collars. But due to the high-risk the personnel executing these type of examinations are exposed to, the use of extra protective devices have become mandatory in the radiology department where the study was carried out.

Nevertheless, digestive examination protocols should be re-evaluated in order to make the necessary changes to reduce the dose to both patient and staff, specially when it is not possible to make changes in the type of equipment used.

(a) (b)

Figure1. Effective dose(a) and dose to the lens of the eye(b) estimated for a period of one year.



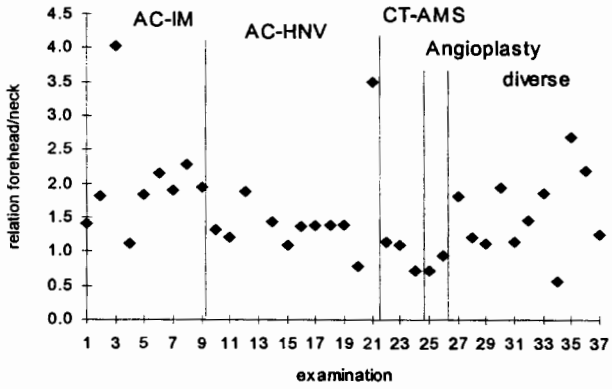


Figure 2. Relation effective dose estimated from dose at forehead/ effective dose estimated from dose at neck level.

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The Changing role of the radiographer under IR(ME)R 2000 .

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ABSTRACT

This paper deals with the way in which the College of Radiographers has used the new Ionising Radiation (Medical Exposure) Regulations 2000 [IR(ME)R] to promote role development among its 17,000 radiographers in the UK. It aims to show that the resultant role development will have a beneficial effect on the radiation protection of the patient in diagnostic radiography.

AIM

To keep radiation doses as low as is reasonably achievable whilst maintaining diagnostic efficiency.

The College of Radiographers, which is the professional body of radiography in the UK and boasts over 90% of all state registered radiographers in its membership, has taken the above statement as their theme over the last year in conjunction with the introduction of the new legislation IR(ME)R 2000.
IR(ME)R 2000 is the statutory legislation, which was laid before parliament in April 2000 and is designated as the Ionising Radiation (Medical Exposure) Regulations 2000 which is based on the adopted European Directive 97/43/Euratom.

The objective of the professional body, which in the United Kingdom is the College of Radiographers, has been to reintroduce radiographers to a sense of personal responsibility for radiation exposure, which is, in fact, part of their Code of Professional Conduct. [1]
The subject of this paper is the importance of the changing role of the radiographer in diagnostic imaging due to the implementation of IR(ME)R.

The introduction of IR(ME)R legislation in May 2000 has given the College of Radiographers the opportunity to run country wide seminars to introduce members to a new interpretation of their responsibilities.
Under the previous legislation POPUMET (Protection of Persons undergoing Medical Examinations and Treatments Regulations 1988) it seemed possible to defer the responsibilities of physically directing radiation to a third person, the clinically directing radiologist.

The new legislation, IR(ME)R, has a far more robust framework and sets out much more clearly the areas of responsibility for each duty holder post, these being the practitioner, operator and referrer.
These duty holder posts are defined as "a health professional who is entitled in accordance with the employer's procedures to take responsibility for an individual medical exposure"(practitioner). "any person who is entitled in accordance with the employer's procedures to carry out the practical aspects" (operator) and " a healthcare professional who is entitled in accordance with the employer's procedures to refer individuals for medical exposure to a practitioner" (referrer).[2]

The policy of the Society and College of Radiographers states [3] "Under these new regulations a radiographer is able to act as a referrer, practitioner, and operator within the field of specialisation defined by his or her expertise, training and continuing professional development. Only these personal attributes and circumstances determine which healthcare professional in any team assumes the role of operator, practitioner or referrer. Profession or discipline alone should not be used to determine duty-holder roles."

The new legislation has led to an unprecedented level of cooperation between some of the professional bodies associated with healthcare in the UK. The Dept of Health (DOH), Institute of Physics and Engineering in Medicine (IPEM), British Institute of Radiology (BIR), Royal College of Radiologists (RCR), Society and College of Radiographers (SCOR) and the National Radiation Protection Board (NRPB) all worked together in the early stages of consultation of the Draft regulations and suggested a number changes which were indeed incorporated in the final Legislation. Following on from that, implementation of the legislation is being expedited by further collaboration of the same working group to firstly identify any training needs of the post holders and secondly to set national Diagnostic Reference Levels (DRL) for as many examinations as seems practical.

The change of emphasis from POPUMET to IR(ME)R has led to the responsibility for the exposure of the patient to doses of ionising radiation becoming the remit of the Operator (notwithstanding that a Practitioner has already carried out justification).
Radiographers are by definition operators and their appraisal of the relevance of the request to the particular individual patient is probably better than most other healthcare professionals. If the duty of the practitioner in justifying the examination is also carried out by a radiographer, and this is quite likely in some modalities, then the likelihood of patients undergoing an individual exposure to radiation that is unnecessary could be considerably lessened.

Under IR(ME)R the radiographer can take on the role of referrer, practitioner and/or operator and it may well be that, whilst not all radiographers will do all of the above, this reallocation of roles will provide continuity and establish good quality decisions about patient examinations across the board. Ionising radiation is not always the correct diagnostic tool and a referral to, perhaps, Ultrasound or Magnetic Resonance Imaging may be the more suitable course of action.

A radiographer as a practitioner will be named by the employer as such in his or her own field of clinical specialism and would not be expected to perform that role in any other area of work. This will ensure that clinical expertise is used judiciously and in the best interests of the patient. It is acknowledged that even senior experienced radiographers might need a little more clinical training before becoming practitioners and will certainly have to be able to prove ongoing competence with continuing professional development.

The new regulations place a far greater responsibility on the employer to ensure that protocols and standard operating procedures are in place. This will be best achieved by calling in the expertise of the radiographer working in that modality and providing input into the content of these standard operating procedures. The duties of the referrer, operator and practitioner need to be defined, explained and training undertaken locally so as to comply with the local procedures and protocols. These should be written in a way that allows a radiographer to make a professional judgement on supplementary views. The radiographer's skill and experience in this field is vital in making IR(ME)R workable. Few other clinical staff can make these judgements safely. The professional judgement used by radiographers as operators must be protected in spite of local "written protocols" if we are to maintain the ethos that "all radiographers are legally accountable for their professional actions and for any negligence by act or omission or injury"(Code of Professional Conduct)[1]
Para 2.7 of the Society and College of Radiographers Guidance for Radiographers [3] states, " the actions of other professionals do not absolve the radiographer of this responsibility". This will be achieved by rigorous and regular audit of systems and procedures including looking at the relevance of referral criteria and the right to refuse a request if it is inappropriate or not justified.

From all of the above observations it may be surmised that by compliance with IR(ME)R in the workplace, having due support from the employer down through all the duty holders, then radiation dose to the patient may be consistent with the ALARA (As Low As is Reasonably Achievable) principle. This should result in recordable and hopefully diminishing doses to individual patients.

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Occupational Exposures from Selected Interventional Radiological Procedures

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1. Abstract

The number of radiology and cardiology interventional procedures has significantly increased in recent years due to better diagnostic equipment resulting in an increase in radiation dose to the staff and patients. The assessment of staff doses was performed for cardiac catheterization and for three other non-cardiac procedures. The scattered radiation distribution resulting from the cardiac catheterization procedure was measured prior to the staff dose measurements. Staff dose measurements included those of the left shoulder, eye, thyroid and hand doses of the cardiologist. In non-cardiac procedures doses to the hands of the radiologist were measured for nephrostomy, fistulogram and percutaneous transluminal angioplasty procedures. Doses to the radiologist or cardiologist were found to be relatively high if correct protection was not observed.

2. Introduction

Providing proper radiation protection to the staff in interventional radiological procedures can pose a real problem. The radiologist and other staff members are usually working close to the area under examination and receive the dose primarily from scattered radiation from the patient. The use of ceiling mounted protection screens is often limited because of their inconvenience.
Due to the different nature and complexity of interventional procedures, they were divided between cardiac and non-cardiac groups and were treated separately in this study.
The recommendations of Goldstone following the review of occupational exposures in interventional radiology [1] have been taken into account in this study.

2.1 Cardiac procedures

The equipment used in Tawam Hospital is a Philips digital BV-5000 bi-plane unit. During cardiac catheterization procedures both x-ray tubes situated on C-arms work either simultaneously or separately. The cardiologist is positioned close to both x-ray tubes and the area under investigation as shown in Figure 1. It is apparent that the left hand side of the cardiologist performing the procedure is particularly at risk.

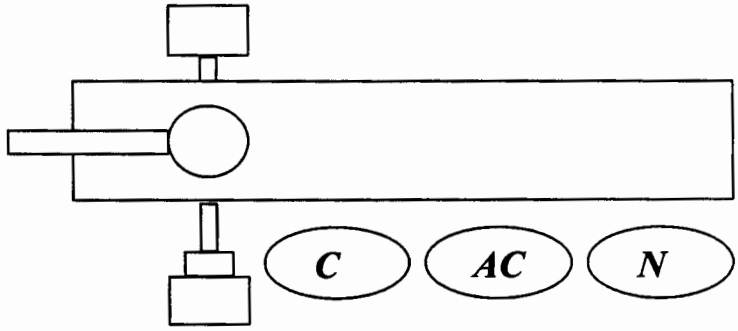

Figure 1. Positions of cardiologist (*C*), assistant cardiologist (*AC*) and nurse (*N*) during cardiac catheterization procedure.

2.2 Non-cardiac procedures

All non-cardiac procedures were performed on the Philips BV-5000 unit, using only single plane. The following typical procedures performed at Tawam Hospital were investigated:

- Upper extremity - fistulogram
- Renal - nephrostomy
- Lower abdomen - percutaneous transluminal angioplasty (PTA) + stenting

For non-cardiac procedures the limiting factor is the hand dose [1]. Radiologists performing them were issued finger dosimeters which were than read after a number of procedures.

3. Method

As a part of our quality assurance and radiation protection program, scattered radiation dose distributions resulting from cardiac catheterization procedures are measured in areas close to the patient [2]. Prior to the measurement, analysis of 10 cardiac procedures involving patients of average size (60 – 80 kg) was performed. The mean dose area product (DAP) resulting from the whole procedure was calculated as 11.8 $Gycm^2$ and used as a reference value in subsequent measurements. The cardiac procedure was recreated using a Rando Alderson phantom as a scattering medium. A 3-D structure containing thermoluminescent detectors (TLD) was positioned close to the phantom where the cardiologist, assistant cardiologist and the nurse would be positioned during the procedure.

The present study focuses on the radiation doses received by the cardiologist left arm, eye lens, thyroid and hands resulting from cardiac procedures. TLDs calibrated for skin dose measurements in the diagnostic energy range were attached to the cardiologist left and right arm, close to the eye lens, on the skin above the thyroid and on the fingers of both hands. Doses to eye lens and the thyroid were later calculated. After each procedure DAP values were recorded and TLD readings were corrected for the average procedure. No lead glass protective screens were used in the procedures covered by the study.

Radiologists performing non-cardiac procedures were issued finger dosimeters. In these cases TLD readings were also corrected for an average procedure in each group using calculated mean DAP.

4. Results

Cardiac procedures The results of scattered dose distribution measurements presented in Figure 2 show relatively high doses with rapid variation in intensity. The highest scatter dose level occurs as expected at the location of cardiologist left arm.

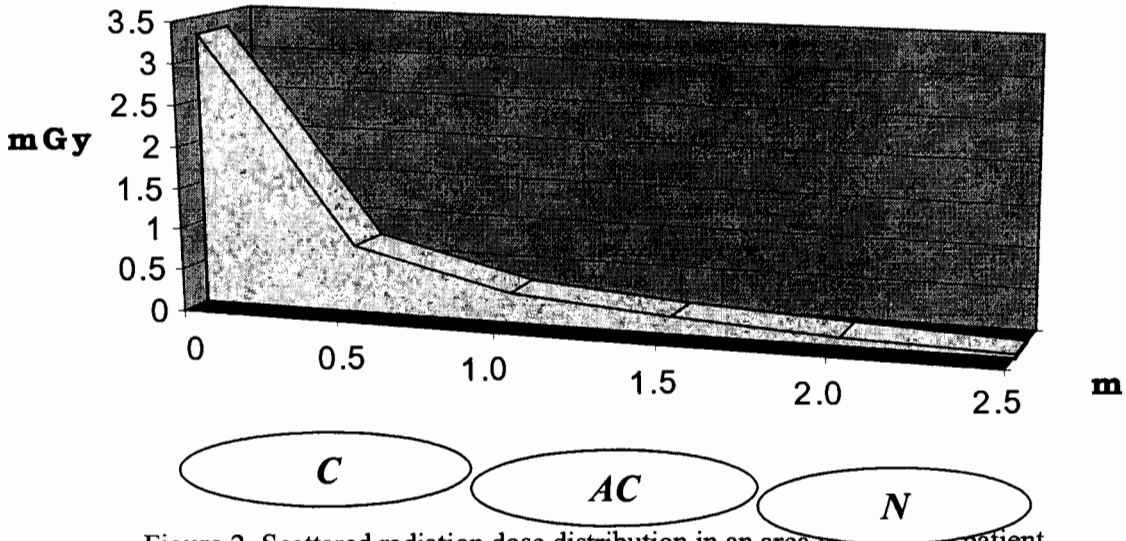

Figure 2. Scattered radiation dose distribution in an area close to the patient.

Sachets containing TLDs were attached to appropriate locations of the cardiologists performing the procedure. Each procedure was closely watched by a monitoring team recording protective measures used and working habits of the staff. In some cases cardiologists did not use protective glasses or thyroid shields due to personal discomfort. A printout indicating fluoroscopy time, number of images acquired and DAP values was obtained at the end of each procedure.
The results of the measurements are presented in Table 1 together with explanations.

Table 1. Values of doses per average procedure in cardiac catheterization

TLD location	Calculated dose (mGy)	
	Situation 1	Situation 2
Left shoulder surface	0.86	---
Thyroid	0.054	0.62
Eye lens	0.068	0.65
Right hand	0.36	---
Left hand	0.19	---

Situation 1 – protective glasses with side shield and thyroid shield worn
Situation 2 – no protective glasses and thyroid shield

Some cardiologists work closer to the C-arm structure and hence X-ray sources. In those cases the left arm dose was measured as high as 1.85 mGy.

Non-cardiac procedures Hand dose is a limiting factor for non-cardiac procedures [1] as thyroid and eye can be adequately shielded. The hand doses have been measured in our hospital for the most common procedures performed. The radiologists were issued finger dosimeters consisting of a TLD-100 chip sealed in a plastic foil envelope. These were fixed to the index fingers of the radiologist before each procedure. The results presented in Table 2 show the average hand dose per procedure.

Table 2. Values of hand doses per average procedure

Procedure	Personal dose (mGy)	
	Left hand	Right hand
Fistulogram	0.54	0.38
Nephrostomy	0.65	0.39
Percutaneous transluminal angioplasty	0.42	0.22

5. Conclusions

Personal doses measured during our survey generally agree with those reported in the literature [1], [3]. The staff were informed about the results of the survey and the following recommendations concerning radiologists and cardiologists performing interventional procedures were issued:

1. Lead aprons used must be at least 0.35 mm Pb equivalent
2. Thyroid shields and protective glasses with side shields must be used.
3. Radiation resistant gloves must be used.
4. Regular radiation protection training to increase awareness of the staff.
5. Regular radiation protection audits to be performed in order to check the implementation of these recommendations.

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Radiation doses to neonates and issues of radiation protection in a special care baby unit

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Abstract

Radiographs are most commonly taken in the neonatal period to assist in the diagnosis and management of respiratory difficulties. Frequent accurate radiographic assessment is required and a knowledge of the radiation dose is necessary to make the justification of such exposures.

A survey of radiation doses to neonates from diagnostic X-ray examinations (chest and abdomen) has been carried out in the special care baby unit (SCBU) of the Royal Free Hospital. Entrance surface dose (ESD) was calculated from Quality Control measurements on the X-ray set itself. Direct measurement of radiation doses was also performed using highly sensitive thermoluminescence dosimeters (LiF:Mg,Cu,P), calibrated and tested for consistency in sensitivity.

The mean ESD per radiograph was calculated to be 36μGy (with a standard deviation of 6μGy), averaged over 95 X-ray examinations. The ESD's as derived from the TLD crystals, ranged from 18μGy to 60μGy. The mean energy imparted (EI) and the mean whole body dose per radiograph were estimated to be 14μJ and 10μGy respectively. Assuming that neonates and foetuses are equally susceptible to carcinogenic effects of radiation (it involves an overestimation of risk), the radiation risk of childhood cancer from a single radiograph was estimated to be of the order $(0.3\text{-}1.3)\times10^{-6}$. Radiation doses compared favourably with the reference value of 80μGy ESD published by CEC in 1996.

1. Introduction

Diagnostic radiology plays an important role in the assessment and treatment of neonates requiring intensive care. It is often necessary to perform a large number of X-ray examinations depending upon the infant's birthweight, gestational age and respiratory problems. X-ray examination of children, especially neonates, attracts particular interest because of the increased opportunity for expression of delayed radiogenic cancers as a consequence of relative longer life expectancy. Also, the small sizes of the newborn infants brings all organs within or closer to the useful beam resulting in a relatively higher overall exposure per radiograph than may be the case with adults. It is therefore important to ensure that radiation doses from radiographic examinations carried out in neo-natal units are kept to a minimum while maintaining the quality of radiographic images.

Wide variations have been found in techniques, equipment performance and radiation dose in different hospitals in a European survey of paediatric radiology [1]. The results have highlighted the need to develop dose standards for paediatric and neonatal examinations. The requirement towards dose optimisation, led to the European Commission recommending a standard radiological technique for neonates with the aim of at least achieving a "reference entrance skin dose" of 80μGy [2].

This paper describes a prospective study of radiation dosimetry performed in the SCBU at the Royal Free Hospital. A variety of dosimetric quantities: ESD, EI and whole body dose have been measured and recorded. Finally, an attempt has been made to evaluate the applicability of TLD LiF: Mg,Cu,P as a reliable dosimetry method used in a SCBU.

2. Materials and Methods

All radiographic examinations were performed with a capacitor discharge mobile X-ray unit type 38S(GEC) with a single phase generator, total filtration 3.6mm aluminium equivalent thickness, and an X-ray tube target angle of 17°, using Kodak Lanex Regular Screen combination with a 400 relative film-screen combination speed. In most cases the examination was carried out with the baby in the incubator and placed directly on the top of the cassette with the focus-to-film distance (FFD) set at 100cm. Pieces of lead rubber were placed on the perspex top of the incubator in order to reduce the size of the X-ray beam to the area of interest. More detailed description about the way that the pieces of lead may be placed on the perspex top of incubator can be found in [3].

2.1 indirect method of measurements

Measurements of tube output were made using a 15cc ionisation chamber with calibration traceable to a national standard. ESD was estimated for each patient and for each exposure from

knowledge of the technique factors, X-ray tube output and backscatter factors (BSF), in accordance with the following formula:

Entrance surface dose (μGy) = output (μGy mAs^{-1})×mAs×BSF×ISL× $(\mu_{en}/\rho)_{tis}/(\mu_{en}/\rho)_{air}$

A BSF of 1.1±5% was employed, determined by [4] for a neonate with body thickness of 5cm with tube potentials in the range 50-70kVp for a field size of 70-300cm^2 using Monte Carlo techniques.

The ISL factor is an inverse square law correction from the chamber calibration distance (100cm from the focus) to the focus-to-skin distance (FSD). The FSD was not measured directly, but approximated by the difference between the known FFD and the neonate equivalent diameter. Because of difficulties in obtaining an accurate measurement of the length or trunk diameter, we used an average equivalent patient diameter of 7.5±1.4cm [5].

The mass energy absorption coefficient ratio averaged over the X-ray energy spectrum was evaluated for muscle as defined by the International Commission on Radiation Units and Measurements (ICRU) and is equal to 1.05 for the range of 50-58kVp used in this study, with an uncertainty of no more than ±1% [6].

The uncertainty in ESD was calculated as the quadrature sum of the estimated uncertainties in output measurement (±3.2%), the use of patient diameter in the ISL correction (±5%) and the BSF evaluation (±5%) to give a value of ±8%.

The EI to the neonate is derived from the ESD integrated over the irradiated area (dose-area product, DAP). The irradiated body area from each radiograph was deduced from measurements made on the film. This area varied widely, owing to different patient sizes but mainly to the varying degrees of collimation employed. The DAP can be approximated by the product of the ESD and the film area demagnified from the FFD to the FSD. This approximation results in a DAP evaluation including backscatter, since the ESD has been calculated after applying the BSF's. The EI is calculated from the estimated DAP using conversion factors for neonates exposed to X-rays with energies between 50 and 70kV_p determined by [4] for a single-phase generator, an anode angle of 17° and a net filtration of 2.5mm aluminium equivalent. Estimates of radiation risk can be made from EI, by assuming that all radiosensitive organs are considered uniformly distributed through the irradiated portion of the body [4]. A whole body dose is determined by dividing the imparted energy by the weight of the neonate.

2.2 direct method of measurements

In this study TLD LiF:Mg,Cu,P (Harshaw TLD-100H) is employed. Only a few reports [7] have studied the performance of LiF:Mg,Cu,P in neonatal X-ray dosimetry. Annealing and read-out of the TLD chips were performed according to the instructions of Qados company [8].

A dedicated calibration employing a perspex jig and tissue substitute phantom, was performed using the X-ray unit on the SCBU. The jig held the TLD chips and calibrated 15cc ionisation chamber. The TLD were individually calibrated and sensitivities established over the exposure range that they would be measuring. The phantom supported the jig and consisted of 1cm slabs of solid water (WT1) which when stacked represented different patient thicknesses.

To ensure that the TLD chips would not actually show up on the films and would not obscure the anatomical and pathological details, the packaged chips were placed on different thicknesses of solid water and irradiated with the X-ray mobile unit. The image quality test showed that the chips are seen in the radiographic image when 4 and 5cm of solid water was used. Consequently, the most appropriate place to put them was considered to be in the X-ray beam, on the shoulder of the baby, if a chest X-ray and on the hip of the baby, if an abdomen X-ray is being performed.

3. Results and Discussion

3.1 Indirect patient dose measurements

A total of 30 neonates were included in this study. The mean number of radiographs received by one neonate was 3.2, which compares with values of 3.8 [9], 5.3 [4] and 4.7 [5] in other studies. Approximately one half of neonates received only one radiograph, but the frequency distribution shows a long tail, with a maximum of 17 radiographs for one neonate. The main influence on the estimated typical total body dose is the number of radiographs taken, which is related to the clinical problems of the neonates. The neonates having a great number of radiographs (above 35 was reported in the studies of [4] and [9]) are of particular concern since they may have an increased probability of

further radiography in early childhood. Dosimetry and protection measures will have special benefit for these children.

ESD's ranged from 28μGy to 58μGy. The mean ESD per radiograph was calculated to be 36.3μGy, averaged over the total of 95 X-rays included in the study. The results of our study show that infants did not receive what might be considered 'excessive' radiation from diagnostic modalities. ESD's were found below the EC reference dose for mobile chest X-rays of 80μGy [2]. Although this is encouraging it should not lead to complacency, as being below the reference dose is not an indication of optimum efficiency.

A more significant measure of risk is the EI to the neonate; only a few studies [4,5,9] have considered this quantity in SCBU radiology. The mean EI and the mean whole body dose per radiograph were found to be 14μJ and 10μGy respectively. The mean EI per radiograph is found to be higher (16μJ) for chest and abdomen examinations than for chest X-ray examinations (13μJ). This shows that the total EI depends strongly on the radiation field area and this is the reason why X-ray beam collimation is important in radiographic examinations. Estimates of radiation risk can be made from EI, by assuming that all radiosensitive organs are considered uniformly distributed through the irradiated portion of the body [4]. The problem is what factor is the most appropriate risk factor for the neonates. The alternatives are whether to correlate our data with the studies on foetuses in utero, or to assume that the sensitivity to ionising radiation for the newborn babies is more similar to that ascribed to young children. In practice of radiation protection, since the majority of neonates were pre-term the appropriate risk factor was felt to be that for fetal irradiation. According to the ICRP report 60 [10] the risk of fatal childhood cancer due to prenatal exposure has been estimated to vary from 2.8×10^{-2} Sv^{-1} to 13×10^{-2} Sv^{-1}. The authors stress that the risk in the first trimester appears to be larger than that found in the 2nd and 3rd trimester, but this is not established. If we accept that the cancer risk, meaning leukaemia, is the same for the 2nd and 3rd trimester it should be fairly close for X-rays taken shortly after birth. Therefore, using these factors, the risk of childhood cancer from a single radiograph would be of the order $(0.3\text{-}1.3)\times10^{-6}$. However, the assumption that the newborn and foetus are equally susceptible to carcinogenic effects of radiation involves an overestimation of risk. Firstly, irradiation in utero involves whole body exposure of the foetus, whereas the neonatal radiography involves only partial exposure. Secondly, it is not known whether babies in a higher oxygen tension than foetuses run a greater risk of carcinogenesis from radiation [11].

The results show the risk from neonatal radiation to be fairly low, and it is considered to be substantially outweighed by the clinical benefit of the radiograph in assessing the progress of a sick baby. This is probably even more marked in the tiny prematures. However, the risk versus benefit of each radiograph is important and must be weighed carefully, especially because radiation effects are cumulative.

3.2 Direct patient dose measurements

Table 1 gives the results from TLD measurements for each examination and gives a comparison between ESD's measured with TLD and ESD's calculated from technique factors.

Table 1: *Comparison between ESD measured with TLD and ESD derived from the technique factors*

Number of radiographs	Mean ESD measured with TLD (μGy)	Mean ESD calculated from technique factors (μGy)
30	28.9±0.4	31.8±2.5

Comparison between the two measurement techniques shows that dose levels are similar for both techniques. These results indicate that TLD LiF:Mg,Cu,P can be applied as a reliable dosimetry method for effective monitoring of dose levels within a special care baby unit.

Uncertainties in the measurement of doses involve the fact that the TLD chips were not placed on the centre of the radiation beam during the X-ray examination, so as not to affect image quality. Since they were placed on the edge of the beam (shoulder/hip), they measured somewhat lower dose. In fact, a difference of the order of 7% in dose was found. Furthermore, uncertainties in the calculation of ESD's from technique factors involve statistical uncertainties in patient's weight, in equivalent patient diameter and in measurements of kV, mAs and FFD.

3.3 Comparison with previously published results and assessment of dose reduction techniques in a SCBU

Our results may be compared with previously published data to attempt to delineate mechanisms for dose reductions. The mean ESD per radiograph, regarding chest X-rays, found in this study (36μGy), can be compared with the values of 36μGy [9], 44μGy [12], 20μGy [5] and 53μGy [13] given by other studies. The mean ESD per radiograph as far as chest and abdomen examinations are concerned, is found to be 35μGy in this study, whereas values of 70μGy and 58μGy have been reported by [11] and [14] respectively. The comparison shows a range of doses resulting from variations in radiographic techniques used and from differences between irradiated populations included in each site. The use of rare-earth screens enables a great dose reduction and should be a major consideration in sites that still use conventional (fast calcium tungstate) screens. In spite of the recommended high voltage techniques, lower radiographic voltage is still often used in most of the sites. It must be remembered that the effective radiographic voltage depends on the type and age of the generator. Not all the generators allow short exposure times that are required for higher kV technique.

The range of ESD's encountered between different studies demonstrates that the 'as low as reasonably achievable' (ALARA) principle is not being applied. Therefore, investigation into further reduction should be made but without compromising diagnostic information. Probably the most significant factor in radiological technique, regarding radiation protection for both infant and staff, is the careful collimation of the field to the area of interest. Therefore, the risk of radiation to the newborn is minimized by making sure that only essential radiographs are taken, that careful collimation confines radiation to the relevant part of the infant, that radiation shields over the lower abdomen are used unless this area is to be included on the radiograph. Finally, adequately trained staff perform the radiographs so that the number of repeat radiographs is reduced to the absolute minimum and that the highest standards of radiation protection are achieved.

4. Conclusions

Although the radiation risk of X-ray examinations is found to be low considering the benefit for the infant, radiography of newborns should be performed with full knowledge of the possible harmful effects, considering that infants are particularly susceptible to radiation induced cancer and that prematures may require a large number of X-ray examinations during the early weeks of life.

Comparison between different studies resulting in a large range of doses found in a SCBU shows a continuing need for assessment of radiation dose on neonates together with regular review, and implementation, of dose reduction procedures.

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Practical Implementation of the Medical Exposure Directive (97/43) in Luxembourg with special reference to diagnostic reference levels

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Abstract
The Council Directive 97/43 EURATOM of June 30th 1997 requires Member States to promote the establishment and use of diagnostic reference levels for radiodiagnostic examinations. In response to this requirement Luxembourg decided to launch a dose measurement campaign for all hospitals and clinics and to compare the results with the diagnostic reference levels recommended by the European commission. Entrance surface dose measurements were carried out for three common examinations (chest, pelvis and lumbar spine) in five hospitals, using thermoluminescent dosimeters. The results showed that for the examinations of the chest and lumbar spine the european reference dose levels were consistently exceeded in four out the five hospitals. This was due to: the use of continuous mode fluoroscopy for positioning the patient, the use of film-screen speed classes below the recommended 400 and the use of a kVp lower than that recommended by the European commission. An optimisation process was carried out in one hospital and entrance surface dose measurements were repeated. It was found that the optimisation process led to a dose reduction of 70%.

1. Introduction

The aim of the Council Directive 97/43 EURATOM of June 30th 1997 [1] on health protection of individuals against the dangers of ionising radiation in relation to medical exposure is to **harmonise** the existing legislation in this field within the member states in order to provide a high level of protection to the patient. Article 4, paragraph 2 of the Directive states that Member States shall promote the establishment and use of diagnostic reference levels for radiodiagnostic examinations, and the availability of guidance for this purpose having regard to European diagnostic reference levels where available. Luxembourg decided to adopt these European diagnostic levels [2] in its legislation and to start a dose measurement campaign in every hospital and clinic.This paper presents the first results obtained from this dose measurement campaign.

2. Method

Quality control tests were carried out on the radiological equipment used for conventional radiological examinations in five hospitals. This was done in order to ensure that the equipment functioned correctly and most importantly that the dose delivered by the equipment was within acceptable limits [3].
Entrance surface dose measurements were carried out using thermoluminescent dosimeters (TLDs) which were fixed on the patients skin. The measurements were done for three standard examinations : Thorax, pelvis and lumbar spine, for 25 patients per examination with an average weight of 70 Kg. The method used was based on a document published by the European comission [4].
For each examination the following paremeters were registered:

- patient parameters:
  - age
  - sex
  - height
  - weight
- technical parameters:
  - sensitivity of intensifying screens
  - kVp used

- mAs
- film size
- use of automatic exposure control
- film to focus distance (FFD)

_ existence of written protocols
_ positioning of the patient: use of fluoroscopy instead of light beam diaphragm
_ number of projections
_ clinical examination by the practitioner before exposure

The data obtained was evaluated and compared with the diagnostic reference levels and technical parameters described in the relative European commission document ìEuropean Guidelines on Quality Criteria for Diagnostic Radiographic Imagesî (EUR96) [2].

3. Results

Properly written protocols for each type of examination didnít exist in any hospital. Proposed written technical parameters existed but were rarely consulted. Fluroscopy was used in every hospital for the positioning of the patient for the examinations of the pelvis and lumbar spine. For the examination of the thorax only one hospital didnít use fluoroscopy for the positioning of the patient and this was due to the fact that the equipment used was a wall stand bucky with no possibility of fluoroscopy. The number of projections demanded for the examination of the lumbar spine was excesive in one hospital i.e. eight projections. In all hospitals no clinical examination was carried out prior to the exposure by the practitioner and in only two out the five hospitals the practioner saw the patient after the exposure.

Figures 1 to 5 show the results obtained from the entrance surface dose measurements. In four out of the five hospitals the European reference levels were exceeded. The reasons for this are the following:

- systematic use of continuous mode fluoroscopy for the positioning of the patient
- use of a kVp which was too low compared with that recommended [2]
- use of intensifying screens of a lower sensitivity compared to that recommended [2]

Only one hospital had entrance surface dose levels below the recommended European diagnostic reference levels [2] and this was due to two reasons:

- its radiological equipement had the option of pulsed fluoroscopy and this option was used for positioning the patient
- it was equiped with intesifying screens of a much higher sensitivity than that recommended [2].

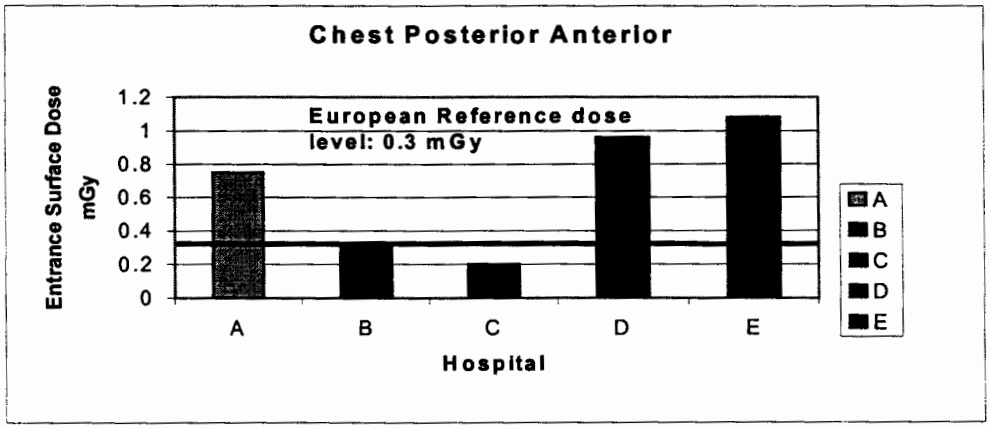


Figure1 1

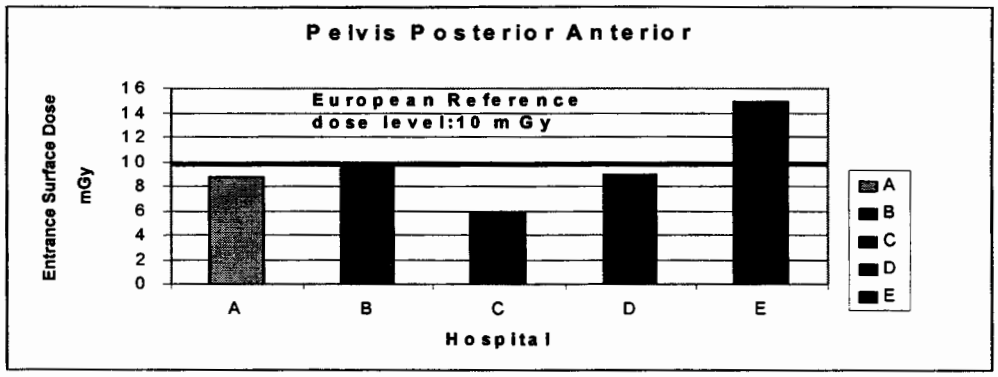


Figure 2

Figure 3

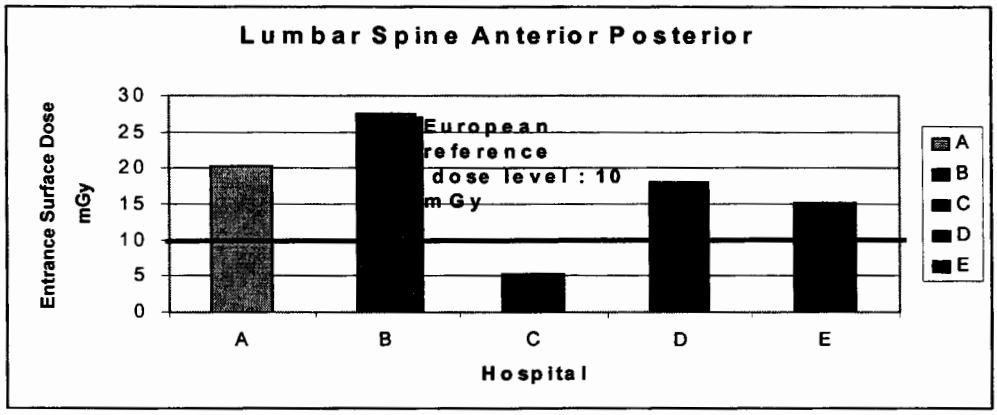


Figure 4

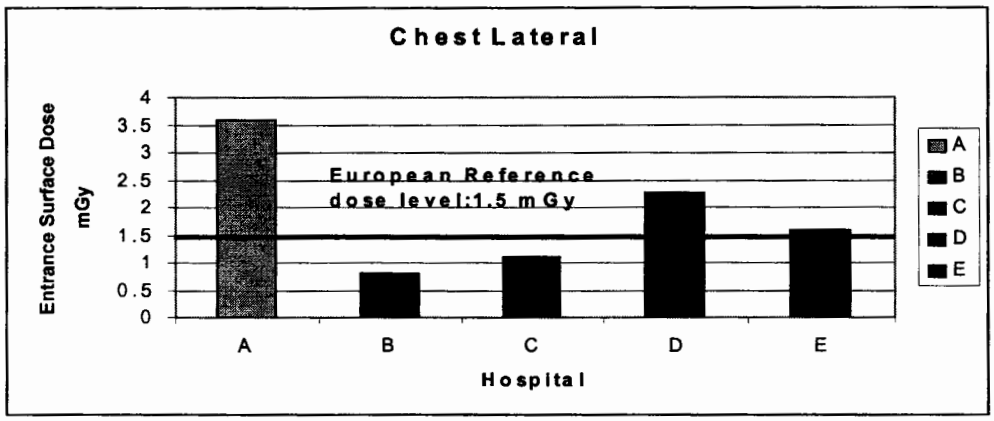
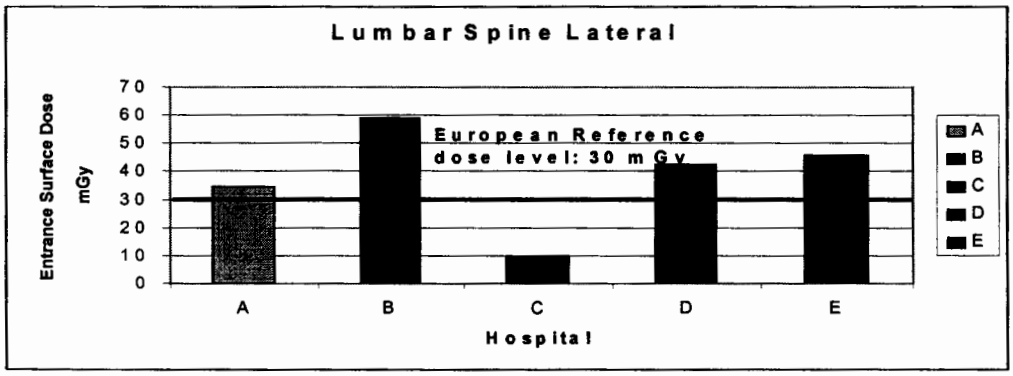


Figure 5



In hospital A (fig. 1-5) the technical parameters were optimised, the use of fluoroscopy for positioning the patient was stopped and written protocols were implemented. The entrance surface dose measurements were repeated and it was found that the entrance surface doses were reduced by 70%.

4.Conclusion

The measurement of entrance surface doses in order to establish diagnostice reference levels is an excellent tool for researching the actual situation in hospitals as far as radiological examinations are concerned. It is perfect as a tool for optimisation purposes i.e achieve entrance surface doses as low as reasonably possible and for training the personnel involved in the radiology departments.

The use of fluoroscopy for positioning purposes should be put on the European Agenda, as this practice isnít limited to Luxembourg.

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Communicating Risks and Benefits of Medical Exposures to Patients

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Abstract

An information leaflet for concerned patients is in preparation, which attempts to explain the risks and benefits of diagnostic medical exposures in terms suitable for the layman. In view of the wide variability in patient doses for the same examination and the considerable uncertainties in radiation risk coefficients, x-ray examinations have been divided into just four broad categories each spanning a factor of 10 in risk. The doses are put into perspective by comparison with those from natural background radiation. Sufficient quantitative information on the approximate level of the risks for some common diagnostic procedures is provided to allow patients to make an informed decision on whether the benefits, as described by the referring clinician, outweigh the radiation risks.

1. Introduction

It is not easy for members of the public in the UK to obtain information on the radiation risks associated with diagnostic medical exposures. Doctors who refer patients for medical imaging examinations using ionising radiation are also not always well informed in these matters and concerned patients frequently resort to NRPB for advice. The NRPB website provides answers to a list of 'frequently asked questions' about medical exposures (which are accessed about 40 times a week) and we deal with one or two direct telephone enquiries each day. However, not all concerned patients have internet access or are aware of the existence of NRPB, so there is a need for more readily available information clearly expressed for the layman.

Consequently NRPB, in collaboration with the Royal College of Radiologists (RCR), the College of Radiographers (CoR) and the Royal College of General Practitioners (RCGP), are preparing a special information leaflet for patients. It is primarily intended to meet the following objectives:

- to inform concerned patients about the risks and benefits of medical x-rays
- to allay unfounded fears about the hazards of ionising radiation
- to put the risks and benefits of medical imaging into perspective
- to help GPs reassure anxious patients at time of referral
- to help hospital staff reassure anxious patients at time of examination

To ensure widespread availability of the leaflet, particularly at time of referral for x-ray examination, it is planned to include electronic copies on appropriate websites so that referring physicians (e.g. general practitioners) can print off copies as required to give to those patients who express concern. Radiographers and radiologists would have similar access to the leaflet on CoR and RCR websites.

2. How to put the dose levels associated with medical exposures into perspective

The dose levels associated with most types of diagnostic x-ray examination are extremely variable from one hospital to another and from one patient to another. NRPB surveys of patient

doses in the UK indicate that inter-hospital variations in the mean dose delivered for a particular type of x-ray examination span a factor of 4 to 7 (between the 5th and 95th percentile) [1]. Inter-patient variability due to individual differences in physique and pathology can add a further factor of 2 to 3. It is consequently not warranted to be over-precise in attributing 'typical' doses to x-ray examinations. In the leaflet we have simply divided X-ray examinations into four broad effective dose categories, each spanning a factor of 10. Estimates of the 'typical' effective dose for each type of examination were derived from information in NRPB's National Patient Dose Database up to the end of 1995 [2].

The public is generally unfamiliar with radiation quantities and units so it is not helpful to express levels of exposure in 'millisieverts' or to try to explain complex concepts like 'effective dose'. An approach that has proved to be very helpful in our experience is to put medical exposures into perspective with everyday exposures by comparing them with the equivalent period of natural background radiation [3, 4, 5]. Admittedly, this uses the concept of effective dose to make the comparison, but the public only needs to appreciate that the dose measure used is roughly related to the total radiation risk from the exposure. In the leaflet, each of the four broad dose categories is related to the equivalent period of natural background radiation, expressed in a similarly imprecise fashion, e.g. 'a few days', 'a few months' or 'a few years' (see Table below).

X-ray examination *(or nuclear medicine isotope scan)*	Equivalent period of Natural background Radiation	Lifetime additional risk of cancer per examination
Chest Teeth Arms and legs Hands and feet	A few days	*Negligible risk* Less than 1 in a million
Skull Head Neck	A few weeks	*Minimal risk* 1 in a million to 1 in 100,000
Breast (mammography) Hip Spine Abdomen Pelvis CT scan of head *(Lung isotope scan)* *(Kidney isotope scan)*	A few months to a year	*Very low risk* 1 in 100,000 To 1 in 10,000
Kidneys and Bladder (IVU) Stomach - barium meal Colon - barium enema	A few years	*Low risk* 1 in 10,000 to

CT scan of chest	1 in 1000
CT scan of abdomen	
(Bone isotope scan)	

3. How to communicate radiation risks

Feedback on initial drafts of the leaflet from the radiology profession and particularly from members of the public, indicated that there is enormous potential for a leaflet of this sort to appear alarmist, trivialising or patronising, depending on the standpoint of the reader. In an attempt to present a balanced view, we start by explaining clearly what the likely effects of radiation are at the dose levels encountered in diagnostic radiology and, just as importantly, what they are not –

"You will be glad to hear that the radiation doses used for X-ray examinations or isotope scans are many thousands of times too low to produce immediate harmful effects, such as skin burns or radiation sickness. The only effect that is known to be possible at these low doses is a very slight increase in the chance of cancer occurring many years or even decades after the exposure."

The delayed nature of the possible effect is emphasised and very approximate quantitative estimates of the chance of it happening in the remaining lifetime of the patient are indicated in the last column of the Table. Again, in view of the wide variability in the patient doses and the considerable uncertainties in radiation risk coefficients especially when applied to an individual, only broad indications of the risk are justified. The ICRP nominal probability coefficient for all radiation-induced fatal cancers averaged over the whole population (5% per sievert)[6] was used to derive approximate risks for each type of examination. Since each examination category in the Table spans a dose range of a factor of 10, the range in risk indicated for each category also spans a factor of 10. The boundaries of the categories have been chosen to coincide with risk levels that are exact powers of 10.

Having broadly indicated the usually very small chance of delayed radiation–induced cancer following a diagnostic medical exposure, we try to put these levels of risk into perspective. Sir Kenneth Calman, the Chief Medical Officer in the UK at the time of the BSE *(bovine spongiform encephalopathy)* outbreak in British cows, has used the same 'power of 10' classification of risk levels in an attempt to answer the public's questions as to what is meant by "safe" [7]. He suggested using the expressions "negligible", "minimal", "very low" and "low" to describe the level of risk in each category to help individuals to decide whether the risk is acceptable. We have used these same expressions in the leaflet (see Table). An individual's acceptability of any risk depends critically on the perceived personal benefit from the activity giving rise to the risk. So the leaflet emphasises repeatedly that the benefit to the patient from the examination, in terms of making the right diagnosis and consequently giving the right treatment, should always outweigh these relatively small risks.

It is also emphasised in the leaflet that the risks are much lower for older people (who undergo the majority of medical imaging procedures) and a little higher for children and unborn babies (for whom special attention is paid to justifying and optimising medical exposures).

No attempt has been made to compare the risks from diagnostic medical exposures with other risks in daily life, since public perception of both the level and the acceptability of everyday risks is notoriously fickle. For example, we were going to suggest that the 'minimal risk' examinations were as safe as travelling by train (1 in 500,000 risk of death in train accidents per year in UK), until the Paddington train disaster in September 1999. Although this one accident did not substantially increase the risk in the long term, the intense media coverage that it received meant that most people's perception of rail transport safety underwent rapid re-evaluation.

The leaflet concludes with a summary of the important points to remember -

- in radiology departments, every effort is made to keep radiation doses low and, wherever possible, to use ultrasound or MRI which involve no hazardous radiation
- the radiation doses from X-ray examinations or isotope scans are small in relation to those we receive from natural background radiation, ranging from the equivalent of a few days worth to a few years
- the health risks from these doses are very small but are not entirely negligible for some procedures involving fluoroscopy or computed tomography (CT)
- you should make your doctor aware of any other recent x-rays or scans you may have had, in case they make further examinations unnecessary
- the risks are much lower for older people and a little higher for children and unborn babies, so extra care is taken with young or pregnant patients
- if you are concerned about the possible risks from an investigation using radiation, you should ask your doctor whether the examination is really necessary. If it is, then the risk to your health from not having the examination is likely to be very much greater than that from the radiation itself

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Implementation of Diagnostic Reference Levels for X-ray Examinations in the UK

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Abstract

Since 1992 NRPB has maintained a computer database of the results sent in from x-ray departments throughout the UK that are following the *National Protocol for Patient Dose Measurements in Diagnostic Radiology*. Reviews of the database take place every five years, the first occurring in 1995 and the second due at the end of 2000. As well as providing useful information on trends in patient doses in the UK, the reviews will also be used as the basis for deriving and updating national diagnostic reference levels (DRLs). The new regulations implementing the EC Medical Exposure Directive in the UK require that DRLs and procedures for their use be established in every radiology department. Guidance issued by the Department of Health indicates that DRLs can be based on local dose records, if available, but that national reference levels may be adopted in the first instance. Strict justification will be required for setting locally-derived DRLs which exceed any corresponding national levels. The national DRLs will be of considerable value to the smaller x-ray departments that do not have sufficient resources or patient throughput to establish their own.

1. Introduction

Periodic monitoring of patient doses from diagnostic x-ray examinations following a national protocol [1] is widespread throughout the UK, with hospital physicists sending the results of their local surveys to NRPB for national collation. By the end of 1995 the national patient dose database contained the results of over 50,000 patient dose measurements made at 375 hospitals. A review of these data by NRPB [2] revealed that, by then, only about 10% of hospitals were exceeding the reference doses listed in the protocol for 8 common types of x-ray examination, which had been based on a national patient dose survey in the mid 1980s. The 1995 review revealed that the mean and third quartile values of the dose distributions had dropped by about 30% since the earlier national survey. However, although the distributions of typical doses had shifted downwards, the variability between hospitals remained as high as before, indicating a continuing need for reference doses to help identify and bring more into line those hospitals at the top end of the dose range. By 1997, when the new EC Medical Exposure Directive (MED) [3] was published, many UK X-ray departments were already using the 1995 review data [2] to set lower reference doses for local use. Regulations to implement the MED in the UK came into force in May 2000 [4] and include the requirement for all hospitals, clinics and surgeries engaging in diagnostic medical exposures to establish *Diagnostic Reference Levels* (DRLs) and to produce (and adhere to) written procedures for their use. A Working Party was consequently set up by the Department of Health in January 2000, with representatives from all the professional bodies involved in diagnostic medical exposures in the UK, to provide formal guidance on the establishment and use of DRLs.

2. DRLs at the National Level

It was recognised by the Working Party that an urgent first step was to revise the reference doses recommended in the 1992 national protocol [1] to be more representative of current UK practice. Consequently, new national DRLs based on the 1995 review of NRPB's national patient dose database [2] were formally adopted, with the recommendation that they be reviewed every five years. The new set of national DRLs is shown in Table I. It is derived from rounded 3rd quartile values of the distributions of the mean dose on a representative sample of patients at each hospital in the database, for each of 12 types of radiograph and 3 types of complete examination. In accordance with the national protocol, DRLs are expressed in terms of the entrance surface dose per radiograph (including backscatter from the patient) and the dose–area product per complete examination.

Table I. New national DRLs for some common x-ray examinations

Radiograph/Examination	Diagnostic reference level	
	Entrance surface dose (mGy)	Dose-area product (Gy cm^2)
Skull AP/PA	4	-
Skull LAT	2	-
Chest PA	0.2	-
Chest LAT	0.7	-
Thoracic spine AP	5	-
Thoracic spine LAT	16	-
Lumbar spine AP	7	-
Lumbar spine LAT	19	-
Lumbar spine LSJ	36	-
Abdomen AP	7	-
Pelvis AP	5	-
IVU	-	23
Barium meal	-	17
Barium enema	-	32

Although it is not expected that DRLs will be established for *every* type of x-ray examination, there is a need to extend the list beyond the few common procedures shown in Table I. There is a requirement in the MED to pay special attention to medical exposures of children and to procedures involving high doses. Priority is consequently being given to developing a method for establishing reference doses for common x-ray examinations on children and to extending the national database to cover some of the increasingly practised high-dose procedures using computed tomography (CT) and extensive fluoroscopy (for example in interventional radiology).

A method for establishing reference doses in paediatric radiology which are directly related to the size of the patient is discussed in NRPB-R318 [5] and in a paper by Hart and Wall in

these proceedings [6]. Computed tomography (CT) examinations are estimated to be responsible for about 40% of the collective dose from all medical x-ray examinations in the UK, so it is essential that the more common types of CT examination are also included in the national database. A framework for establishing CT DRLs has been developed in European Guidelines on Quality Criteria for Computed Tomography [7], based on the dose quantities, weighted CT dose index ($CTDI_W$) and dose-length product (DLP). This approach to CT dosimetry and its potential use for establishing DRLs at the national level for common CT examinations in the UK, is discussed in a paper by Shrimpton in these proceedings [8].

To extend the range of examinations for which national DRLs can be established, contributors to the national patient dose database have been encouraged to supply data for most of those procedures which are among the top 25 contributors to the collective dose from all medical x-ray examinations in the UK. In addition, to give special attention to children and high-dose procedures, data is encouraged for six common types of paediatric examination and for some of the more common and standardised types of interventional procedure. Consideration is also being given to deriving national DRLs for mammography and dental radiography from the data available in recent extensive patient dose surveys in the UK. It is hoped that the next review of the database in 2001 will form the basis for a substantially revised and extended list of DRLs for consideration by the Department of Health Working Party.

3. DRLs at the Local Level

The new medical exposure regulations in the UK [3] require all hospitals to have procedures in place for establishing DRLs, for the regular assessment of patient doses and for checking compliance with DRLs. Periodic measurements for the purpose of assessing representative patient doses are also required by other legislation dealing with quality assurance of medical imaging equipment [9].

There are basically three options available to hospitals for establishing DRLs locally. They can either adopt the national DRLs, use regional patient dose data to derive essentially regional DRLs and adopt them for local use, or use their own hospital dose data to derive reference levels that are specific to their own practice. If sufficient regional dose data are available from enough hospitals on representative groups of patients, regional DRLs can be established in the same way as the national DRLs. They can have the advantage of being more up to date and more relevant to local practice than the national DRLs, but to be as effective in identifying bad practice, they should be no higher than any corresponding national DRLs.

A hospital may specialise in a medical imaging procedure for which no national or regional DRL is available. In this case, dose data from just the one hospital could be used to establish a typical dose to a representative group of patients for that procedure. This could be used as a "reference dose" against which to assess trends in time at that hospital or to compare different sets of imaging equipment or the procedures used by different "operators". When derived in this way from 'very local data', the reference levels are useful tools for local quality assurance

and clinical audit programmes, but do not necessarily provide a guide to generally accepted good practice.

Local patient dose monitoring is required to establish whether DRLs are being consistently exceeded and whether corrective action is required. The DH Working Party recognised that practical guidance was needed on effective methods for carrying out this monitoring while also complying with the equipment quality assurance requirements of other regulations [9]. The Institute of Physics and Engineering in Medicine (IPEM) consequently convened a Working Party in October 2000 to provide such guidance. It will essentially be an extension of the 1992 national protocol for patient dose measurements [1] giving practical advice on how to comply with all the new requirements of the recent regulations for patient dose monitoring in diagnostic radiology. An IPEM report containing this guidance is planned to be published at around the time of this conference.

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Development of Diagnostic Reference Levels in Paediatric Radiology

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Abstract

With a very wide range in patient size from a newborn baby to a 15 year old adolescent, reference doses for paediatric radiology can sensibly be established only for specific sizes of children. Five standard sizes have been chosen representing newborn, 1, 5, 10 and 15 years. A method is described for normalising the dose measured on a child of any size and age to the corresponding dose to the nearest standard sized patient. Normalisation factors for entrance surface dose and dose-area product measurements were calculated based on effective linear attenuation coefficients (μ) measured in phantoms and calculated by Monte Carlo techniques for the typical x-ray spectra and field sizes used in paediatric radiology. These normalisation factors were applied to European paediatric dose survey data to derive some preliminary size/age specific reference doses for some common radiographic projections and for micturating cystourethrography (MCU), the most common fluoroscopic examination performed on children.

1. Introduction

Patient size is an important determinant of the level of dose received by individuals from diagnostic x-ray examinations and is a confounding factor when assessing and comparing radiation doses to patients in x-ray departments. Variations in size are large between paediatric patients (covering the age range from newborn to 15 years) and the use of a single reference size is impractical. Accordingly, it has been common practice to group children by age in order to facilitate meaningful comparison of dose using age-bands such as: 0–1 month, 1–12 months, 1–5 years, 5–10 years and 10–15 years. However, children within the same age band can still be of considerably different sizes, resulting in up to a factor of three difference between the entrance surface doses to obtain the same exit dose and hence the same dose to the image receptor.

This paper discusses methods for deriving factors for normalising doses measured on actual patients to those relating to patients of the nearest standard size representing 0, 1, 5, 10 and 15 year old patients. This procedure will enable the results of local dose surveys to be compared with reference doses for the same standard–sized paediatric patients. The establishment and use of reference doses as a practical way of promoting optimisation of patient protection is required by the EC Medical Exposure Directive [1], where they are referred to as *diagnostic reference levels*. This approach has also been adopted in the dose criteria for radiographic examinations of adult and paediatric patients in European Guidelines [2, 3]. However, in the paediatric guidelines [3], a European–wide paediatric patient dose survey for common types of radiograph, in which the patients were simply divided into a few narrow age bands, failed to demonstrate any clear trends in dose with age. It was possible to provide only tentative reference doses, mainly for five year old patients, in those guidelines. In this paper, the same European survey data have been re–analysed by normalising the measured doses to those for the nearest standard–sized patient and, where there are sufficient data, new reference doses have been derived for each standard size. As patient thickness had not been measured in the European survey, a method was developed for estimating thickness for the various radiographic projections from the available information on patient height and weight.

2. Selection of standard sizes for paediatric patients

The AP and lateral thicknesses of children of various ages for common radiographic projections through the trunk and the head have been published by Bohmann [4]. These data were used to select the required number and dimensions of standard-sized patients so that normalisation factors were unlikely to exceed a factor of two (i.e. differences in thickness between adjacent standard-sized patients were < 5 cm). The thicknesses of the five selected standard-sized patients are shown in Table I.

Table I. Standard thicknesses for the trunk and head

Age (y)	Standard thickness by beam projection (cm)				
	Trunk AP	Trunk LAT	Head AP	Head LAT	Trunk average (for multiprojection exams of the trunk)
0	8.5	10	12	9	9
1	12	15	16	12	13
5	14	19	18.5	14.5	15
10	16	23	18.5	14.5	18
15	18	27	18.5	14.5	21

When dose measurements (usually of dose-area product (DAP)) are integrated over a complete examination comprising multiple radiographs and/or fluoroscopy, the projection of the x-ray beam is likely to change and may include AP, PA, lateral and oblique projections. In this case separate AP and lateral standard trunk thicknesses are inappropriate and an "average" trunk thickness would be more useful. A simple estimate of patient average trunk thickness can be made from height and weight data by assuming the patient is a circular cylinder of unit density. The equivalent cylindrical diameter (ECD) is given by:

$ECD = 2(weight/\pi.height)^{0.5}$, where ECD and height are in cm and weight is in grams.

2. Derivation of normalisation factors

Assuming exponential attenuation of diagnostic x-ray beams through the patient, the relationship between the entrance surface dose (ESD) and the exit surface dose is given by:

$$\text{Exit dose} = ESD\ e^{-\mu x}$$

where μ is the linear attenuation coefficient for the part of the patient's body being x-rayed, of thickness x, and includes the effect of the inverse square law. For a constant exit dose, the patient entrance surface dose (ESD_x) will vary with patient thickness, x, according to:

$$ESDx = k\ e^{\mu x}$$

Measured values of ESD for a patient of thickness d can, to a first approximation, be normalised to the ESD for a patient of standard thickness, s, which would result in the same exit dose by multiplying by the normalisation factor, F_{ESD} where:

$$F_{ESD} = ESD_s / ESD_d = e^{\mu(s-d)}$$

The factor, F_{DAP}, for normalising DAP measurements for complete examinations involving multiple projections, measured on a patient of known thickness to the nearest standard thickness, is given by:

$$F_{DAP} = e^{\mu(s-d)} . s^2/d^2$$

where there is an additional term to account for the fact that the area component of DAP will increase with patient size roughly as s^2/d^2 (assuming the dimensions of the patient in a plane perpendicular to the axis of the x-ray beam are proportional to the thickness of the patient along the axis of the beam). Appropriate values of μ for the exposure conditions prevailing in paediatric radiology were obtained from measurements of entrance and exit doses on a soft tissue equivalent phantom (WT1 material) representing paediatric patients of 5, 10, 15, and 20 cm thickness with a number of typical diagnostic x-ray spectra and field sizes. A lung equivalent material phantom (using the lung sections of an Alderson Rando phantom) was also used to simulate chest radiography. Exit doses were measured in front of and behind an antiscatter grid (grid ratio 12:1, 36 lines per cm) since the ratio of primary to scattered radiation in the exiting beam is also a function of patient thickness. As the grid removes most of the scattered radiation, the attenuation coefficient derived from the through-grid exit dose was higher than that measured without a grid. Values of μ were obtained from the slopes of graphs of ln ESD per unit exit dose against phantom thickness.

The phantom measurements were verified and extended to a wider range of exposure conditions by Monte Carlo simulation. Remarkably close agreement was achieved (to within 2% without a grid, and 6% with a grid) between the Monte Carlo calculated μ values and those measured in the soft-tissue equivalent phantom. For the lung equivalent phantom the agreement was not so close, but the discrepancy can be quantitatively explained by small soft-tissue components in the lung sections of the Alderson phantom which were not simulated in the Monte Carlo calculations.

Without a grid, values of μ for soft tissue (WT1) range from 0.20 to 0.25 cm^{-1} for the range of x-ray qualities and beam areas likely to be met in paediatric radiology and with a grid from about 0.25 to 0.30 cm^{-1}. They are more dependent on kV than field size over the ranges studied. The measured values of μ for lung are considerably lower than the values for soft tissue and range from 0.11 to 0.13 cm^{-1}.

Using the appropriate values for μ and the thicknesses of standard patients as discussed above, values of the normalisation factors were calculated for a range of patient thicknesses in 0.5 cm increments from that for a small baby to a large 15 year old. The results are tabulated in NRPB-R318 [6]. All F_{ESD} values were no larger than a factor of two up or down, as were F_{DAP} values apart from some of those for very small babies or very large 15 year olds.

3. Derivation of size/age specific reference doses

The wide-ranging survey data collected for the European paediatric radiology trial [3] were re-analysed to develop size/age specific reference doses for common radiographs. Firstly, to eliminate some unacceptable practices, the data were restricted to those from hospitals that were using the tube voltage, film-screen speed and antiscatter grid technique factors recommended in the European Guidelines [3]. Data for patients of any size were included and the ESDs normalised to those for the nearest standard-sized patient using the F_{ESD} normalisation factors discussed above. The thickness of the radiographed section through the patient was derived from patient height and weight data using a method developed by the authors [5]. The distribution of the size-normalised doses from the European trial has been used to derive reference doses for standard-sized paediatric patients based on the rounded third quartile values, as shown in Table II. European reference doses for adult patients [2] are also shown for comparison.

By normalising for patient size and rejecting unacceptable practices, the paediatric reference doses now show a reasonable trend with patient age, which was not evident in the original data [3]. The values, even for a 15 year old child, are substantially lower than those shown for an adult, which reflects the expected additional care taken when children are radiographed and the improvements made in patient protection since the adult reference doses were derived over 10 years ago.

DAP data have been collected for micturating cystourethrogram (MCU) examinations at a sample of 12 European hospitals [5]. Between 10 and 30 paediatric patients were included from each hospital with ages ranging between neonate and 15 years old. However, the majority of patients were under 5 years old as is usual for MCU examinations. Information on weight, height and trunk thickness was collected for each patient. The DAP for each patient was normalised to that for the nearest standard trunk thickness for multiprojection examinations as shown in Table I, using appropriate values of F_{DAP}. The rounded third quartiles of the distributions of the mean normalised DAP values were used to derive the provisional reference doses shown in the last row of Table II.

Table II. Size/age specific paediatric radiology reference dose values

	Reference Dose Value					
	Neonate	1 year	5 year	10 year	15 year	Adult
Radiograph	*Entrance surface dose, mGy*					
Chest AP/PA	0.05	0.05	0.07	0.12	-	0.3
Abdomen AP/PA	-	0.4	0.5	0.8	1.2	10
Pelvis AP	-	0.5	0.6	0.7	2	10
Skull AP/PA	-	0.8	1.1	1.1	1.1	5
Skull LAT	-	0.5	0.8	0.8	0.8	3
Examination	*Dose-area product, Gy cm^2*					
MCU	0.6	0.9	1.2	2.4	-	40[a]

[a] Reference dose for IVU examination on adults

4. Acknowledgements

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REFERENCE DOSIMETRY FOR CT IN THE UK

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Abstract

Computed tomography is firmly established as a major source of population exposure from diagnostic x-ray examinations and thus a particular focus for radiological protection initiatives. The concept of reference doses is widely recognised as a useful and practical tool for promoting improvements in the optimisation of protection for patients undergoing radiological examinations. National diagnostic reference levels (DRLs) have already been successfully applied in the UK for some conventional x-ray examinations within a framework for advice on patient protection. This approach is being extended to include CT, utilising the robust methodology for reference dosimetry that has been developed by the European Commission (EC) for the particular conditions of exposure in CT. This is based on the dosimetric concepts of weighted computed tomography dose index ($CTDI_w$) per slice in serial scanning or per rotation in helical scanning, and dose-length product (DLP) per complete examination. Notwithstanding some initial values proposed by the EC, specific national DRLs for CT practice in the UK will be established on the basis of widescale national survey data.

Introduction

Computed tomography is firmly established as an important tool in diagnostic radiology that provides high quality cross-sectional x-ray images of the body, although the doses to patients are relatively large. Increasing application of this modality has made a substantial impact on both patient care and also population exposure. In developed countries, CT procedures typically represent about 6% of the total number of all medical x-ray examinations, yet provide about 41% of the resultant collective effective dose [1]. Surveys of clinical practice have also demonstrated wide variations in patient dose for a given type of procedure and potential scope for improvement in the optimisation of protection for patients undergoing CT [2].

Whereas it is inappropriate to impose strict limits on the doses received by patients for medical purposes, the concept of reference doses is recognised increasingly as a useful and practical way of promoting the fundamental requirement for optimisation of patient protection, whereby doses are always as low as reasonably practicable in order to meet specific clinical objectives [3, 4]. In essence, reference dosimetry seeks to characterise clinical practice in terms of reference dose quantities that allow simple, yet meaningful comparisons of technique for a given type of procedure. Such dose measurements are intended to facilitate, where needed, improvements in patient protection during the regular process of critical review of equipment and techniques. In particular, diagnostic reference levels can be set for different types of examination on the basis of wide-scale survey data to help identify potentially inadequate performance [5]. This approach has proved effective for reducing unnecessary exposures from conventional x-ray examinations in the UK [6]. A robust methodology for the specific reference dosimetry necessary for CT has already been developed by the European Commission as an integral part of quality criteria for such examinations [7].

Reference dose quantities

The principal dosimetric quantity used in CT is the computed tomography dose index (CTDI). This is defined as the integral along a line parallel to the axis of rotation (z) of the dose profile (D(z)) for a single rotation and a fixed table position, divided by the nominal thickness of the x-ray beam. CTDI can be conveniently assessed using a pencil ionisation chamber with an active length of 100 mm, so as to provide a measurement of $CTDI_{100}$, expressed in terms of absorbed dose to air [8]:

$$CTDI_{100} = \frac{1}{nT}\int_{-50}^{+50} D(z)dz \qquad \text{(mGy)} \qquad (1)$$

where n is the number of tomographic sections, each of nominal thickness T, from a single rotation.

Reference dosimetry for CT is based on such measurements made within standard CT dosimetry phantoms; these presently comprise homogeneous cylinders of polymethylmethacrylate (PMMA), with diameters of 16 cm (head) and 32 cm (body), although phantoms of water-equivalent plastic and with elliptical cross-sections are under development. The combination of measurements made at the centre (c) and 10 mm below the surface (p) of a phantom leads to the following two reference dose quantities [7]:

(a) Weighted CTDI in the standard head or body phantom for a single rotation corresponding to the exposure settings used in clinical practice

$$CTDI_w = \frac{1}{3}CTDI_{100,c} + \frac{2}{3}CTDI_{100,p} \qquad \text{(mGy)} \qquad (2)$$

where $CTDI_{100,p}$ represents an average of measurements at four different locations around the periphery of the phantom.

(b) Dose-length product for a complete examination

$$DLP = \sum_i {}_nCTDI_W * T * N * C \qquad \text{(mGy cm)} \qquad (3)$$

where i is the number of scan sequences in the examination, each with N rotations of collimation T cm and exposure C mAs; ${}_nCTDI_w$ is the normalised weighted CTDI (mGy $mA^{-1}s^{-1}$) appropriate for the applied potential and nominal beam collimation (number and width of slices per rotation).

These quantities can be applied to serial or spiral scanning, for both single- or multi-slice geometry scanners. The dose quantities relate to measurements in the standard head or body dosimetry phantoms, as appropriate to the type of examination, for the exposure conditions used in clinical practice. The concept was initially developed in relation to examinations on adult patients [7], although it has subsequently been extended for application to paediatric CT [9]. Monitoring of $CTDI_w$ per rotation takes account of the exposure settings selected, such as tube current and tube voltage. Monitoring of DLP for a complete examination takes account also of the volume of irradiation, as determined, for example, by the number of slices in serial scanning or the acquisition time in spiral scanning, and the number of such scan sequences conducted during the examination. Such dose data provide useful indications of relative

patient exposure for a given type of procedure. Values of DLP may also be used to derive broad estimates of effective dose for CT procedures using region-specific coefficients [7, 9].

Diagnostic reference levels

Initial diagnostic reference levels have been published for some common procedures on the basis of surveys of practice for adult [7] and paediatric [9] patients at selected hospitals in seven European countries; these values are shown in Tables I and II.

Table I. Initial European reference dose values for CT examinations on adult patients [7].

Examination	Diagnostic reference level	
	$CTDI_w$ (mGy)	DLP (mGy cm)
Routine head[a]	60	1050
Face and sinuses[a]	35	360
Vertebral trauma[b]	70	460
Routine chest[b]	30	650
HRCT of lung[b]	35	280
Routine abdomen[b]	35	780
Liver and spleen[b]	35	900
Routine pelvis[b]	35	570
Osseous pelvis[b]	25	520

[a]Data relate to head dosimetry phantom (PMMA, 16 cm diameter).
[b]Data relate to body dosimetry phantom (PMMA, 32 cm diameter).

Table II. Initial European reference dose values for CT examinations on paediatric patients [9].

Examination	Patient age (years)	$CTDI_w$ per slice or rotation[a] (mGy)	DLP per examination[a] (mGy cm)
Brain	< 1	40	300[b]
	5	60	600[b]
	10	70	750[b]
Chest (general)[c]	< 1	20	200
	5	30	400
	10	30	600
Chest (HRCT)	< 1	30	50
	5	40	75
	10	50	100
Upper abdomen[c]	< 1	20	330
	5	25	360
	10	30	800
Lower abdomen & pelvis[c]	< 1	20	170
	5	25	250
	10	30	500

[a]Data relate to 16 cm diameter PMMA dosimetry phantom.
[b]DLP values for brain refer to single phase examination (with or without contrast).
[c]Examination mainly conducted using spiral scanning.

Such investigation levels are for comparison locally with the mean values of dose descriptors assessed in a CT facility during examinations on representative groups of patients and should not be applied on an individual patient basis.

Specific national DRLs for CT practice in the UK will be established on the basis of widescale national survey data. The present National Patient Dose Database that is used for setting and reviewing national DRLs for conventional x-ray examinations [6] will be extended to include CT.

Acknowledgement

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THE DEVELOPMENT OF STANDARD OPERATING PROTOCOLS FOR PAEDIATRIC RADIOLOGY

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Abstract
This paper describes how the requirement for operating protocols for standard radiological practice was expanded to provide a comprehensive aide to the operator conducting a medical exposure. The protocols adopted now include justification criteria, patient preparation, radiographic technique, standard exposure charts, diagnostic reference levels and image quality criteria. In total, the protocols have been welcomed as a tool for ensuring that medical exposures are properly optimised.

1. Introduction

Great Ormond Street is a specialist children's hospital in the centre of London. The patients, both inpatient and outpatient, attend from a wide area which includes the whole of the United Kingdom and overseas. Almost 7% of patients come from abroad. The services that are provided by the hospital fall into five broad categories: Medical/Urology, Cardiorespiratory and Critical Care, Host Defence, Surgery, and Neurosciences. Between 40% and 50% of the children treated within the hospital are under the age of 2 years. There is a continuing trend to provide increasingly specialist and complex forms of care.

In order to support the work of the hospital the Radiology Department has found itself at the cutting edge of paediatric radiological practice. The department has a team of radiologists, radiographers and nurses working in a dedicated child-friendly environment. Many of the radiological examinations are performed on patients from one of the Intensive Care Units of which there are five. These examinations include complex interventional procedures such as bronchial stent insertions.

The total annual workload for 1999/2000 was 50,000 + examinations of which 28,000+ were general radiography. The department consists of 2 general x-ray rooms, 1 CT scanner, 2 MRI suites, 1 fluoroscopy unit, 3 angiography suites, 3 nuclear medicine cameras, surface topography, 1 bone densitometer, 1 orthopantomograph(OPT) and 4+ ultrasound machines. Much of the general x-ray work is mobile and is undertaken on one of the large intensive care units. There are also 2 mobile image intensifier which are used for per-operative procedures. The department, with the exception of the OPT, is completely digital and a PACS system is to be installed during 2001. There are 30+ whole time equivalent radiographers.

The European Directive 97/43/Euratom [1] stated aim is "laying down measures for the health protection of individuals against the dangers of radiation". During 1999/2000 standard operating protocols were developed within the Radiology Department at Great Ormond Street Hospital in response to the Ionising Radiation (Medical Exposure) Regulations 2000 (IR(ME)R) [2], the UK implementation of the Directive. The regulations place responsibilities upon employers and employees with regard to the radiation protection of patients, with particular reference to special practices such as the medical exposure of children. Included in the regulations is the requirement for standard operating protocols for all examinations using ionising radiation. This has been implemented in all sections of the Radiology Department.

2. Method

Developing new protocols at Great Ormond Street Hospital presented an opportunity to review current practices and improve clinical systems and procedures, thereby enhancing the quality of care to patients. This is in line with the requirements for Clinical Governance, which was introduced to ensure that all National Health Service (NHS) organisations have in place proper processes for continuously monitoring and improving quality. One of the key points of Clinical Governance is that all clinicians must understand their individual and collective responsibilities for assuring accountability for the quality of patient care.

All sections of the department had some established protocols but these were disjointed and in many different formats. Most included only basic procedures and detailed the required 'views' that were needed for specific examinations. None incorporated diagnostic reference levels or referral guidelines. The general protocols did attempt to set down quality criteria taken from the European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics [3], but this was only for basic examinations such as chest, abdomen, skull and spine. It was decided that a department-wide format had to be adopted for new protocols. This would simplify the use of the protocols for radiographers as many worked in most sections of the department.

The new protocols were to represent a handbook for each examination room in the department. Contained in the protocol files were details of everything required for each radiological exposure that might take place in that room. This included referral guidelines, patient preparation, radiographic technique, exposure factors, diagnostic reference levels, image quality criteria, additional projections and common pathologies. In each section of the department a radiographer was nominated to co-ordinate writing protocols for that section. Most radiographers were involved to some degree in the production of the latest versions of the Great Ormond Street protocols.

The final versions of the protocols were specific to:

- General radiography
- Mobile and theatre radiography
- CT
- Nuclear Medicine (1 for each camera)
- Cardiac and Neuro angiography
- Interventional procedures
- Fluoroscopy
- Bone densitometry
- Dental and maxillo-facial radiography

Identical formats were used throughout. Each had a section preceding the main body of the protocols containing procedures that were common to all areas in which a medical exposure might be made. These were:

- Working in radiation areas including:
    - Local rules
    - Methods of reducing dose
    - The ALARP Principle
    - Names and contact numbers for Radiation Protection Supervisors and the Radiation Protection Adviser
- Methods of ensuring quality control
- Administration, including:
    - Examination requesting
    - Reporting of images
    - Updating of details onto databases and film packet, if appropriate

- Procedures specific to mobile and theatre radiography

The relevance of including these in the protocols was to minimise the number of unnecessary examinations resulting from administrative error, to ensure that the dose was always as low as reasonably practicable for the patient and that staff doses were kept to an absolute minimum.

Following the common section the protocols were written for specific area within the department and each contained:

- Valid reasons for the examination, or justification guidelines. IR(ME)R stated that all medical exposures to ionising radiation must be justified prior to exposure to ensure optimisation of the exposure. Justification of a medical exposure is carried out in most circumstances by the Practitioner, which is usually the radiologist. However there are times when an exposure may be authorised by an Operator (the radiographer), with remote justification by the Practitioner [4]. At such times the radiographer uses his/her training and experience to authorise the exposure, but also has the guidelines written in the protocols to aid the authorisation process. Also included are comments which may help the radiographer when explaining how they have arrived at the justification.

- Patient preparation. This section details steps that should be taken before the exposure is made. Included are:
  - procedures such as patient identification
  - removal of objects that might obscure the image
  - preparation of a carer or person who might be required to assist with holding the patient

  These are all procedures that must be carried out in order to ensure optimisation of the exposure and that patients and carers are not irradiated unnecessarily

- Radiographic technique for standard projections including
  - Positioning of the patient and X-ray tube, together with immobilisation techniques that might be used for avoid having to repeat the exposure
  - Radiographic equipment that should be used, or be available to minimise the exposure
  - Recommended focal spot size
  - Recommended use/absence of an anti-scatter grid
  - Recommended imaging modality e.g. Computed Radiography
  - Recommendations as to whether automatic exposure chambers should be used
  - Radiation protection, including accurate collimation, gonad protection, lead masking and protection for holders hands
  - Correct Focal Film Distance

- Exposure factors for different age/weight ranges. The ranges were chosen as a guide to assist with selection of the relevant exposure factors. The age ranges are 0-1 year, 1-5 years, 5-10 years, and 10-15 years. The ages/weights were then included in tables that easily showed the radiographic exposure factors. An example of the exposure factors used is given in Table I.

Table I. Exposure Factors for an AP/PA Chest beyond the neonatal period

Age	kV	mAs
1 - 5 years	70 - 75	3.2 - 5
5 - 10 years	75 - 80	5 - 7
10 - 15 years	75 - 80	4 - 8

- Image quality criteria. These ensure that operators are aware of the standards expected. Audit of images could then be carried out by comparison with the standard criteria. All images were expected to have correct identification, sidemarkers and correct window levels and shuttering. These assist the radiologist when viewing optimal images to ensure diagnosis .

- Diagnostic reference levels [5]. If these are exceeded they are recorded separately for audit purposes. An example of the diagnostic reference levels used is given in Table II.

Table II. Diagnostic Reference Levels for Chest X-Rays

Age	kV	mAs
1 - 5 years	70	3.2
5 - 10 years	75	3.2
10 - 15 years	75	6

- Additional projections to assist the radiographer in their choice of imaging.

- A list of more common pathologies which might be shown by the selected imaging protocol.

3. Conclusions

The introduction of the new standard operating protocols has been very well received by all members of the radiographic staff working at the hospital. They are of particular value when new staff or agency radiographers are working in the department and also when radiographers work in many different areas. As many of the staff were involved in the production of the protocols the radiographers have ownership of them and are keen to see that they are regularly updated. There is therefore a willingness to contribute to the protocol audit programme. Most importantly they are a guide to best practice and are valuable in the optimisation of all medical exposures.

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THE ESTABLISHMENT AND USE OF DOSE REFERENCE LEVELS IN GENERAL PAEDIATRIC RADIOLOGY

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Abstract
Diagnostic reference levels for general paediatric radiology have been established in terms of delivered exposure parameters rather than skin dose or dose-area product. With supporting measurements from equipment quality assurance and assumptions of standard patient sizes it was possible to derive reference levels in terms of entrance surface dose. This allowed comparison to be made with other published data. The reference levels for common examinations are presented for different age bands. There is a notable variation with patient age for some examinations which is not apparent in other published data.

1. Introduction

The Medical Exposure Directive of the European Union [1] and the resultant Ionising Radiation (Medical Exposure) Regulations [2] in Great Britain, call for the establishment of diagnostic reference levels for radiodiagnostic practices for typical examinations for groups of standard-sized patients. These reference levels should be interpreted as an expected upper bound on the radiation dose delivered to an exposed individual under normal circumstances. Such a level is not to be taken as a limit, though investigations should be carried out if the levels are consistently exceeded.

In a specialist paediatric hospital, one is faced with the immediate difficulty of not having a standard sized patient, which leads to multiple diagnostic reference levels for each examination. A further problem arises with the selection of dose quantity for the reference level. For some modalities one can use the same quantities as would apply to adults (dose-area product for fluoroscopy, CTDI or total mAs for computed tomography and administered activity for nuclear medicine). However, difficulties arise in general radiography, where for a number of examinations the preferred dose quantity, dose-area product, can not be used as currently available meters are too insensitive. An alternative approach was therefore adopted for all general radiographic examinations, basing the diagnostic reference levels on exposure parameters and using standard protocols and quality assurance results to link these to more universally recognisable dose indicators.

2. Method

It was decided to adopt five commonly used age bands for paediatric dosimetry, namely <1 year, 1 to 5 years, 5 to 10 years, 10 to 15 years and 15+ years. Once reference levels have been determined for each age group and dose data surveyed, it may be possible to refine these age bands and reduce the number of different levels set.
The standard operating protocols for general radiography [3] include guidance on typical exposure parameters to set for the age bands given above. Variation in patient size and clinical requirement calls for flexibility within each band, and so a range of exposure parameters is usually quoted. Table I gives an example of the exposure guidance in the standard operating protocol for routine chests.

Table I. Sample Exposure Chart for PA Chest X-Rays

Age Band	kV	mAs
<1	60 – 65	2.0 – 2.5
1 – 5	65 – 70	2.0 – 3.2
5 – 10	70 – 75	2.5 – 3.2
10 - 15	70 – 75	3.0 – 6.0

The exposure parameters were selected following prolonged assessment of image quality on a recently installed computed radiology imaging system. This assessment is ongoing, and may result in further changes being made in the future.

As a starting point, the diagnostic reference level (DRL) for each examination was set to the maximum kV/mAs combination recommended for each age band. For example, the DRL for a PA Chest on a 7 year old child would be 75kV and 3.2mAs.
There is a requirement in the Directive, and in the national legislation, to have regard to European diagnostic reference levels where available. Such data as there is on paediatric doses tends to quote dose levels (and hence DRLs) as entrance surface dose (ESD). In order to make comparison with this data, and to contribute to the pool of available dose levels, it was therefore necessary to convert from kV/mAs to entrance surface dose. This was achieved using quality assurance measurement to determine the dose in air at the distance equivalent to the entrance surface and to make tissue:air and backscatter corrections in order to arrive at a skin dose at that point [4]. The equation used for this calculation is:

$$D_{surface} = D_{air} \frac{(\mu_{en}/\rho)_{muscle}}{(\mu_{en}/\rho)_{air}} \left(\frac{L}{FSD}\right)^2 BSF$$

where L is the output measurement distance, FSD is the focus skin distance, BSF is the backscatter factor and μ_{en}/ρ is the mass energy absorption coefficient for the given medium.

Routine quality assurance on the general radiology equipment included radiation output measurements at 10kV intervals across the diagnostic range, and at fixed kV for a range of mAs values. The total filtration of the beam is also assessed routinely. Given that the relationship between kV and output is of the form [5]

$$\mu Gy/mAs \propto kV^n$$

the value of n was determined from the gradient of a logarithmic plot and the radiation output calculated for any intermediate kV value.

The standard operating protocol for each examination specifies a focus to image receptor distance. The focus to entrance surface distance was determined from this by subtracting the patient thickness. Direct measurement of this would place a significant burden on the operator, so standard thickness values were taken from published data [6]. Radiation output at this distance was then calculated using an inverse square correction from the standard output measurement distance.

To correct for dose to tissue, the ratio of mass energy absorption coefficients for tissue and air was included. A value of 1.06 was assumed to be valid across the diagnostic energy range [4].

The backscatter factor depends on X-ray beam quality and field and patient size. Backscatter fraction data have been published by the National Radiological Protection Board (NRPB) for typical examinations for children of different ages [7]. Their data is tabulated for different kV and beam filtration values. Values corresponding to the kV and filtration used were derived from this data set by linear interpolation.

Table II presents the results of the calculations based on the current diagnostic reference levels in use at the hospital. The 5th column gives the calculated entrance surface dose. The 7th and 8th columns make comparison with published data from the European Commission [8] and Hart et. al. [6] respectively. In each case the authors quote values for a specific age, rather than age range. To assist with comparison, their quoted values are tabulated to correspond with our upper age range. For example, a DRL for a 5 year old is placed alongside our 1 – 5 year old data. The 6th column presents estimates of effective dose using Monte-Carlo factors published by the NRPB [7].

Cases where DRLs have been exceeded are recorded separately and investigations triggered if the proportion of cases exceeds 25% of the total number performed within the audit period.

Table II. Calculated Diagnostic Reference Level (DRL) as Entrance Surface Dose (ESD)

Examination	Age Band	DRL kV	DRL mAs	ESD (μGy)	E (μGy)	ESD (μGy) Ref [8]	ESD (μGy) Ref [6]
Skull AP	<1	65	4	266	5.1		800
	1 to 5	65	8	546	6.2	1500	1100
	5 to 10	67	10	728	5.6		1100
	10 to 15	70	13	1051	8.7		1100
Skull LAT	<1	65	3.2	193	4.7		500
	1 to 5	65	7	440	6.0	1000	800
	5 to 10	67	8	532	6.5		800
	10 to 15	70	10	738	7.7		800
Chest PA/AP	<1	65	5	83	8.1		50
	1 to 5	70	3.2	64	6.9	100	70
	5 to 10	75	3.2	77	8.6		120
	10 to 15	75	6	148	10.8		
Chest LAT	<1	65	4	69	7.3		
	1 to 5	75	5	123	11.7	200	
	5 to 10	80	7	209	18.5		
	10 to 15	80	8	256	15.4		
Abdomen AP	<1	63	2	121	21.6		400
	1 to 5	65	4	273	46.9	1000	500
	5 to 10	65	12	868	132.0		800
	10 to 15	75	16	1649	196.2		1200
Pelvis AP	<1	63	2.5	149	18.6	200	500
	1 to 5	65	4	271	37.4	900	600
	5 to 10	65	12	864	76.9		700
	10 to 15	75	16	1646	158.8		2000
C-spine AP	<1						
	1 to 5						
	5 to 10	65	5	323	14.1		
	10 to 15	65	6	442	18.0		
C-spine LAT	<1						
	1 to 5						
	5 to 10	70	8	171	3.9		
	10 to 15	75	12	331	6.9		
T-spine AP	<1						
	1 to 5						
	5 to 10	75	10	913	102.2		
	10 to 15	80	16	1792	401.4		
T-spine LAT	<1						
	1 to 5						
	5 to 10	85	16	2254	209.6		
	10 to 15	85	20	3193	196.4		
L-spine AP	<1						
	1 to 5						
	5 to 10	75	16	1536	146.2		
	10 to 15	70	20	1748	111.7		
L-spine LAT	<1						
	1 to 5						
	5 to 10	75	25	2806	102.7		
	10 to 15	85	25	4102	111.6		

3. Conclusions

The diagnostic reference levels established at Great Ormond Street Hospital for general paediatric radiography are easy to use as they are in units which correspond to the exposure chart in each room and do not vary according to the examination. As more sensitive DAP meters become available the hospital may move towards using this quantity for the DRL, but it is unlikely that routine skin doses would be measured.

One of the potential drawbacks to using a kV/mAs combination for a DRL is that it is possible to exceed the DRL whilst giving a lower dose to the patient. For example, giving an exposure of 76kV and 2.5mAs for a PA Chest on a 7 year old child would exceed the DRL (75kV and 3.2mAs) but would result in a lower skin dose. The impact of this will be assessed as cases of DRLs being exceeded are audited in the future.

With regard to age bands, there is scope for reducing the number of bands in examinations where the skin dose derivation of the DRLs varies little. There is, however, clear indication that some examinations have a steep rise in dose with patient age. The European Commission guidelines [8] only quote data for 5 year old children in most circumstances, stating that entrance surface dose values they collated varied little between infants and 5 and 10 year old children. The data from Hart et. al. [6] shows little variation in reference level with age for some examinations (e.g. skull), but quite marked variation in others (in particular for the pelvis). It should also be noted that there are some marked differences in values reported in the two references (e.g. for a 5 year old abdomen).

If the results presented here are of interest to other paediatric centres, it should be emphasised that the exposure parameters are being adapted to a computed radiology (CR) system, which has required considerable changes. In particular, the move to reduce patient dose by increasing kV and reducing mAs leads to poor image quality in paediatric CR as the mAs falls too low to avoid quantum noise. The lower absorption edge of the CR plates compared to intensifying screens in cassettes suggests that image quality is optimised at lower kVs and a new balance must therefore be found between dose and image quality. The parameters quoted here represent the current status in the optimisation process.

4. References

[1] Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing Directive 84/466/EURATOM. (OJ L-180 of 09/07/97).

[2] The Ionising Radiation (Medical Exposure) Regulations 2000. Statutory Instrument 2000 No. 1059, Her Majesty's Stationery Office, London (2000).

[3] HARDWICK J., et al,. IAEA-CN-67/17, these Proceedings.

[4] WALL B.F., et al., Patient Dosimetry Techniques in Diagnostic Radiology. Rep. 53, IPSM, York (1988).

[5] CRANLEY K., Measurement of the Performance Characteristics of Diagnostic X-Ray Systems Used in Medicine. Rep. 32 Part I (2nd Edition), IPEMB, York (1995).

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[7] HART D., et al., Normalised Organ Doses for Paediatric X-Ray Examinations Calculated using Monte-Carlo Techniques. Rep. NRPB-SR279. Didcot (1996).

[8] European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics. EUR 16261, European Commission (1996).

THE JUSTIFICATION OF A MEDICAL EXPOSURE – WHO DOES IT?

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Abstract
It is widely acknowledged that the use of ionising radiation in medical exposures must be justified, but it has often been difficult to determine who makes that justification, and who is responsible for it. New legislation introduced in the UK following the European Union Medical Exposures Directive makes it necessary to ensure that justification takes place and to ensure that the individuals responsible for it are identified and are adequately trained. This paper presents an approach to justification which minimises the need for extra training by focussing responsibility for justification on professionals who have gained sufficient knowledge as part of their specialisation. By acknowledging the role of radiographers in the justification process and allowing them flexibility in their judgement, it is proposed that the justification process will become more robust and should screen out inappropriate referrals more effectively.

1. Introduction

Article 3 of the Medical Exposures Directive [1] requires that all medical exposures should be justified in advance, ensuring that there is sufficient net benefit to the individual to be exposed, or to society, to offset the detriment associated with the use of ionising radiations. Article 5 indicates that the prescriber and the practitioner shall be involved in the justification, with their respective responsibilities left to the member state to determine.

In Great Britain, the Ionising Radiation (Medical Exposure) Regulations 2000 [2] places the responsibility for justification on the practitioner, with the referrer (i.e. prescriber) required to provide relevant medical data. The regulations require the practitioner to be adequately trained, and provide a syllabus of training, but otherwise impose no restriction on the profession of a person entitled to act as a practitioner. In the current climate of skill mixing and role extension there has been considerable local debate on whether the radiographer should be entitled to justify medical exposures or whether this should remain the responsibility of the radiologist. There has also been discussion on the role of medically qualified personnel other than radiologists in the justification process. The syllabus for adequate training is a daunting prospect for some professions, e.g. orthopaedic surgeons, whose use of radiation for medical exposures is well defined and limited.

The approach presented here has been adopted by our respective hospitals, and has been scrutinised by the appropriate regulatory authority in Great Britain.

2. The Practitioner

The Medical Exposures Directive describes the Practitioner as the medical doctor, dentist or other health professional who is entitled to take clinical responsibility for an individual medical exposure in accordance with national requirements. This definition is transferred to the legislation in Great Britain with a regulation that the practitioner is responsible for the justification of a medical exposure.

When implementing the Ionising Radiation (Medical Exposure) Regulations within our hospitals it was necessary to define at an early stage who our practitioners would be. In the UK all qualified radiologists have passed exams for Fellowship of the Royal College of Radiologists and will have received a Certificate of Completion of Specialist Training, also from the Royal College of Radiologists. By this mechanism it is ensured that radiologists have adequate theoretical and

practical training to undertake the role of practitioner. Other staff groups require additional training to meet the requirements of the regulations. Guidelines on training issued by the European Commission [3] suggests that interventional cardiology specialists, other medical doctors, and dentists should have between 20 and 30 hours training in "core knowledge", with more detailed training for some groups. It is recommended that such training be delivered via basic residency programmes and specialist courses. Until such training is made available nationally as part of medical or specialist training for medical staff other than radiologists, it was decided that the most pragmatic approach would be to reduce the numbers of persons who would require this level of additional training. Having taken into account the amount of radiation being used by medical staff groups, the complexity of the procedures for which they would need to be responsible, and their degree of autonomy in using radiation, it was decided that the hospital would entitle radiologists, cardiologists and dentists to act as practitioners. Of these, the cardiologists and dentists would, at the moment need additional training before being entitled to justify medical exposures. For staff currently practising in these roles, account would be taken of existing training and experience and any shortfall picked up in a continuing education programme.

Other medical staff groups, such as orthopaedic surgeons, gastroenterologists, endoscopists and urologists would be identified as referrers (prescribers) and not be required to train as practitioners or as operators provided a qualified radiographer acting as operator is present for the exposure. The arrangements for this are described in the following section.

It was also decided that the radiographer effecting the exposure would not be a practitioner.

3. Authorisation of Exposures

The Ionising Radiation (Medical Exposure) Regulations require all medical exposures to be justified in advance and authorised. The authorisation would normally be undertaken by the practitioner at the time of justification, most simply by endorsing the proffered referral form. However, the regulations do provide for those situations which may arise when referrals are made out of normal working hours when a practitioner is not available, or in general diagnostic radiology where there may be insufficient radiologist cover to individually authorise every exposure. In such instances it is possible for the operator to authorise the exposure in accordance with guidelines issued by the practitioner. In effect, the practitioner retains the responsibility for justifying the medical exposure, but issues justification criteria to the operator performing the exposure such that the operator can make the authorisation.

4. Authorisation Guidelines

As there is no defined content to the guidelines it was possible to adopt an approach which fitted in with the structure adopted by the hospital for the process of a medical exposure and which recognises the professional qualification, experience and training of the radiographer. The general guideline now in place requires radiographers to exercise their judgement within the bounds of their knowledge and experience, and allows them to authorise exposures with reference to justification criteria. These justification criteria are included in the standard operating protocol for every radiological procedure carried out within the hospital [4]. The text of the current general guidelines is reproduced in Figure 1 below. As an example, the justification criteria for the chest X-ray of a neonate would be:

- Abdominal Pain
- Bowel Obstruction (Erect CXR)
- CCAM
- Chest Pain
- Congenital Cardiac Anomaly
- Cough
- Cyanosis
- Dyspnoea
- Fever
- FTT Neuroenteric Cyst
- Hypoxia
- Haemoptysis
- ICU - Tube Change
- Inhaled Foreign Body
- Lung Abscess
- Tachyphnoea
- Murmur
- Non Accidental Injury (NAI)

- Sequestration Chest Of Abdominal Trauma
- Systemic Disorder Or Skeletal Dysplasia
- VP Shunt Series

General comments for the procedure would be included, for example it is stated that routine pre-operative chest X-ray in a well child is not indicated, and that mobile x-rays carry a potentially higher radiation dose and should be reserved for children too unwell to come to radiology department.

Figure 1. Text of Current Authorisation Guidelines

General Guidelines for Operators Authorising Exposures

These guidelines apply to medical exposures where it is not practicable for the practitioner to be present to authorise individual exposures. It is expected that practitioners will make themselves available to authorise the following classes of examination:

- CT - all examinations except CT heads
- Cardiology - all procedures
- General fluoroscopy – all procedures
- Vascular (including neuro) - all procedures
- Nuclear Medicine – all procedures.

It follows that operators should not authorise the above classes of examination, but should seek such authorisation from the practitioner on duty in that area according to the local rota.

Provided the operator is a qualified radiographer, registered to practice radiography in the UK, and can demonstrate active participation in continuing professional development, the task of authorising a medical exposure can be delegated to that operator. In so doing it is expected of the operator that they will use their professional knowledge and experience, coupled with an awareness of best practice advocated nationally or locally within the Trust, to determine whether the medical exposure proposed is the most appropriate for the individual presented. In reaching this decision the operator must take full account of any clinical details accompanying the request, and must refer the request back if it is deemed that there is insufficient detail. They must also take account of all the information given in the Standard Operating Protocol for the exposure proposed.

When authorising an exposure, the operator must consider:

- the objectives of the exposure and the characteristics of the individual involved;
- the potential benefit and detriment to the exposed individual; and
- the efficacy, benefits and risk of alternative techniques involving less or no exposure to ionising radiation.

Special consideration must be given to females where pregnancy cannot be excluded, where potential dose to the unborn child must also be taken into account.

Special consideration must also be given to breastfeeding females undergoing nuclear medicine procedures, where dose to the child must also be taken into account.

If the operator is unable, due to lack of experience in the area, to decide on an authorisation, the request, and the task of authorisation, may be passed on to a suitably qualified/experienced operator or to the duty practitioner. The operator must never authorise exposures for which they know themselves not to be qualified.

From time to time, practitioners within the Trust may issue written supplements to these guidelines which offer advice on specific cases (eg pre-operative chest X-rays). Such supplements will be entitled "Supplementary Guidance on Authorisation of Exposures" and will be endorsed by the Clinical Director of Radiology. These must be adhered to.