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

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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

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]

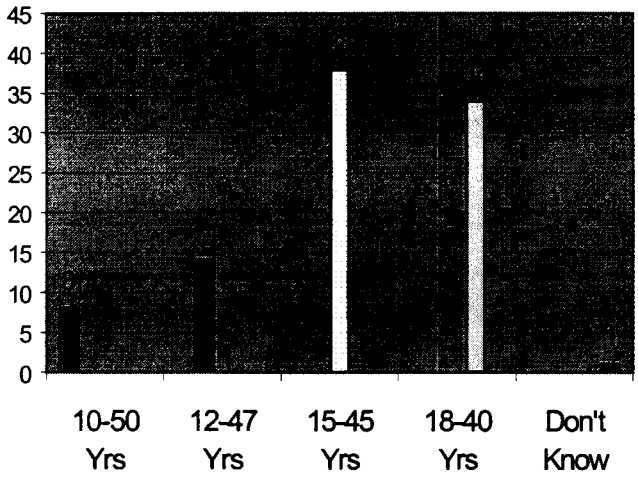

Figure 2 – Child bearing age n = 95

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.

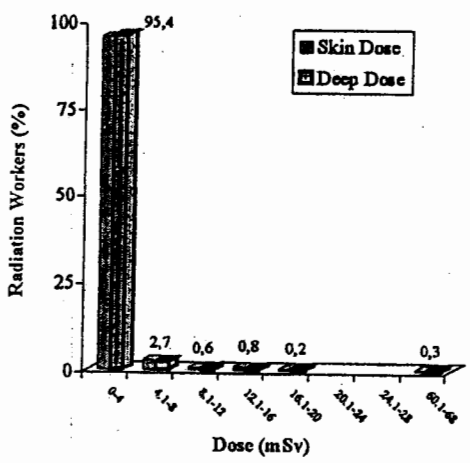

Fig.1. Distribution of External Radiation Dose from 1994 - 1999

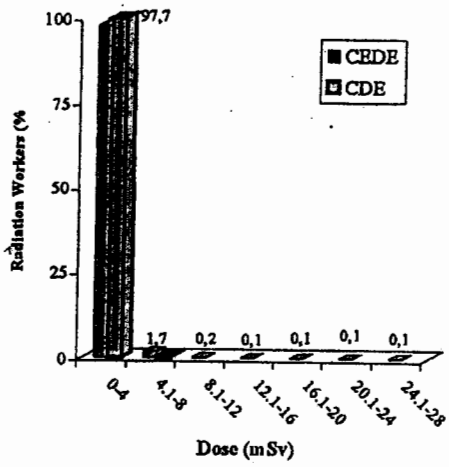

Fig.2. Distribution of Internal Radiation Dose from 1994 - 1999

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

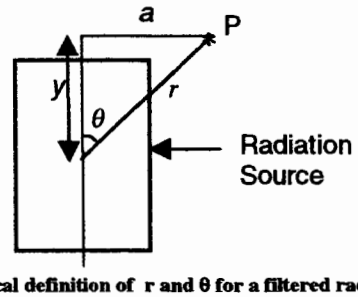

figure 1. The geometrical definition of r and θ for a filtered radiation source

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.

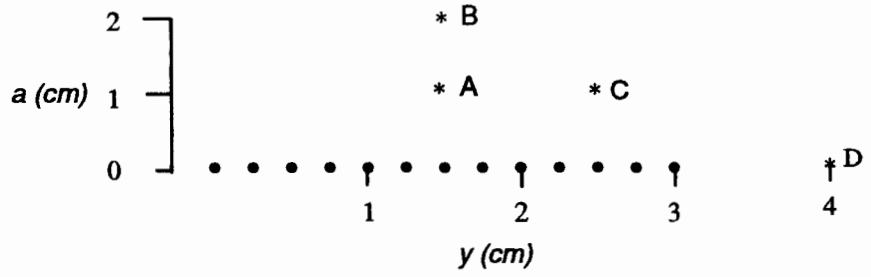

Figure 2. Illustration of example: •, dwell point; *, calculation point

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.

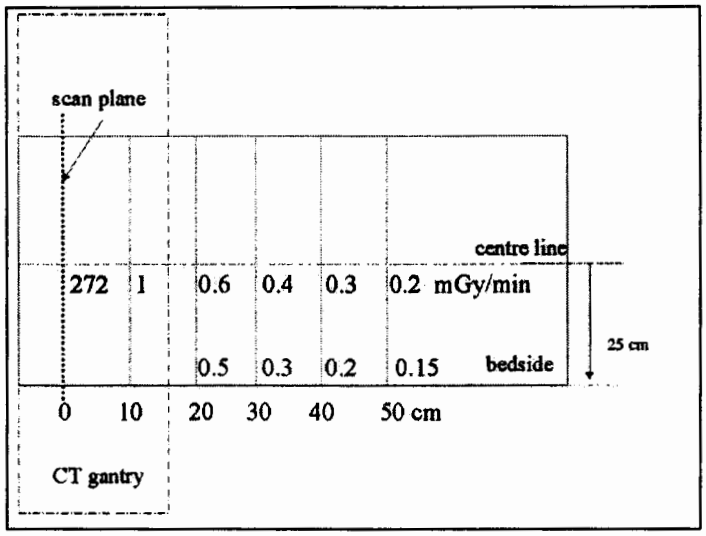
Patient Dose

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.

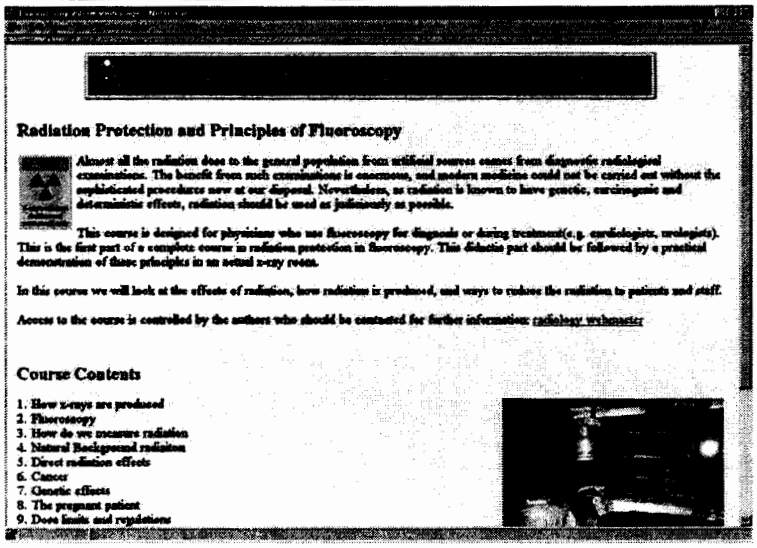
Finally, the button bar on each page of content provides direct access to any course tool that has been included on that page by the designer. These might include links to that page's multiple-choice questions, a link to a conference forum for that page of notes, or a link to reference material for that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

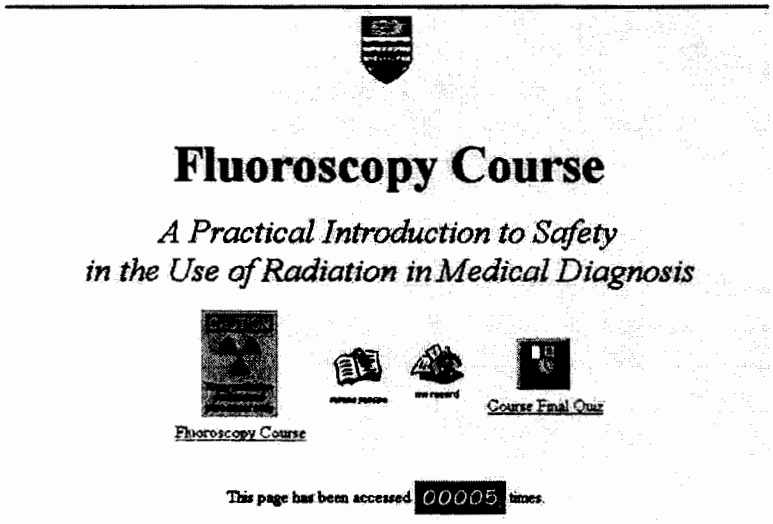
Course Contents

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

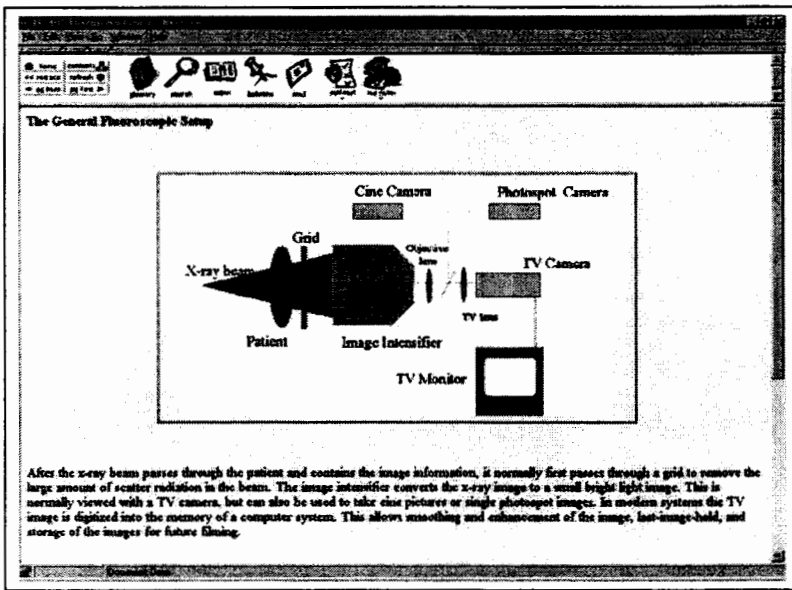
A Practical Introduction to Safety in the Use of Radiation in Medical Diagnosis

Fluoroscopy Course

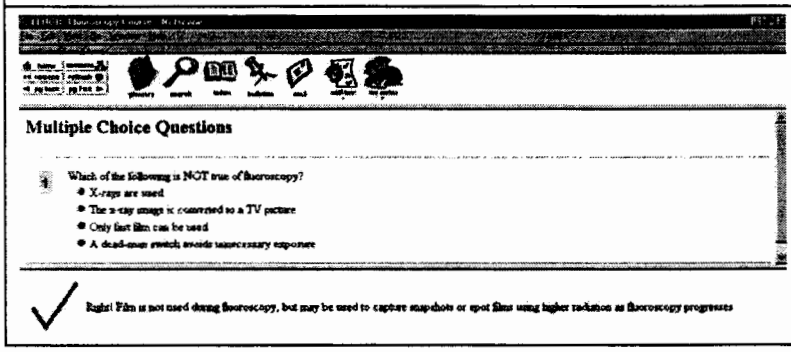
Course Final Quiz

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

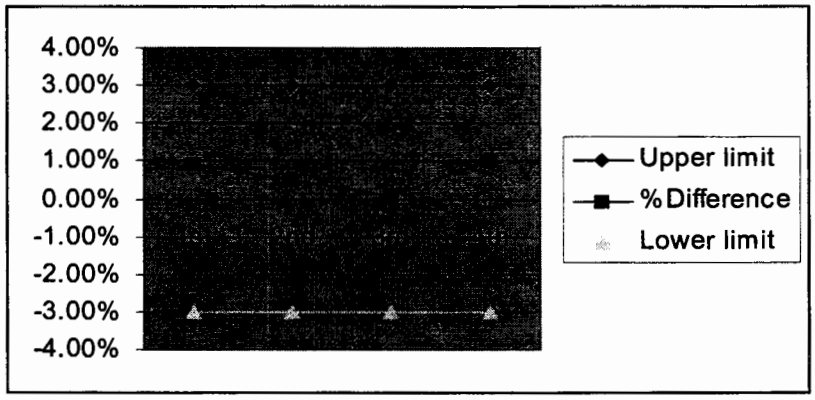

Figure 1 Source calibration accuracy

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

[1] International Basic Safety Standards for Protection Against Ionizing Radiation, Safety Series 115, International Atomic Energy Agency, Vienna Austria (1996)

[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)

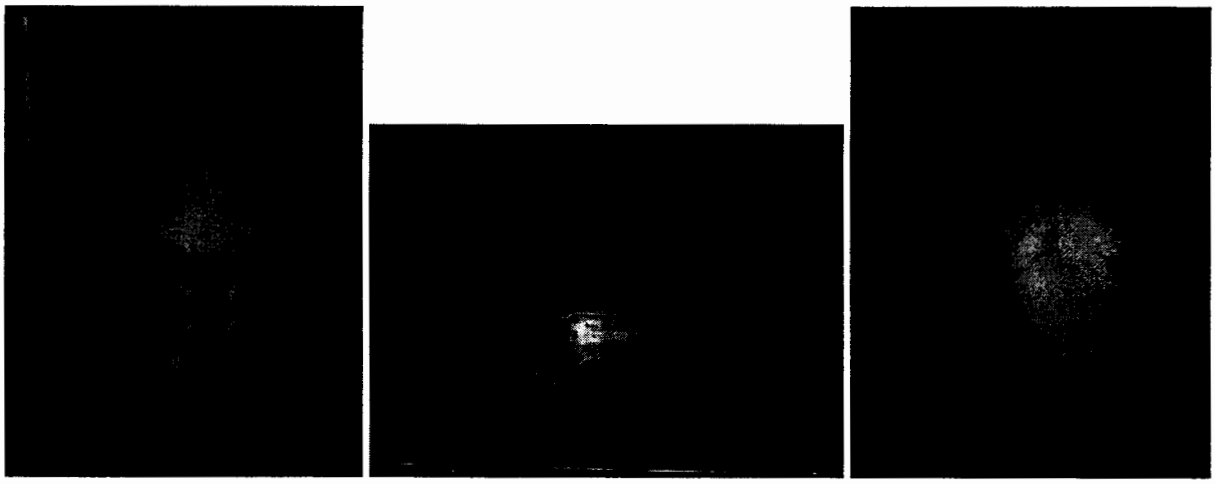
	Poor	Satisfactory	Good
Group I (SID = 100 cm)	1	15	20
Group II (SID = 125 cm)	0	21	27

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)

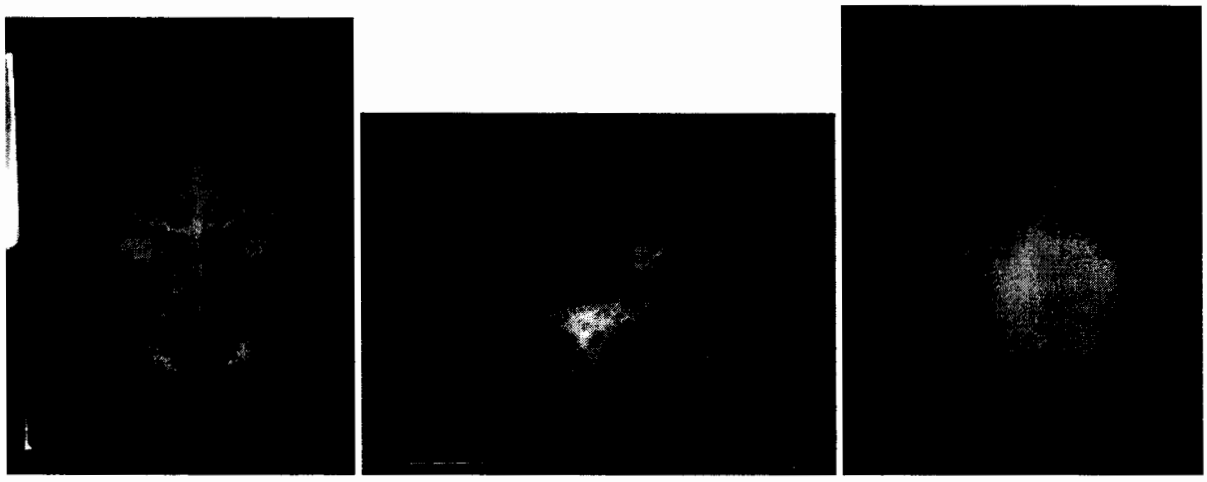


a b c

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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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.