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THE RADIATION DOSE AND DRUG INTERACTION WITH RADIOPHARMACEUTICAL: THE EFFECT OF MITOMYCIN-C ON THE BIODISTRIBUTION OF THE ^{99m}TECHNETIUM-PYROPHOSPHATE IN MICE

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ABSTRACT

The biodistribution of radiopharmaceuticals may be modified by drug interaction. Unknowledge of such factor can induce a poor misvisualization of the scintigraphy images, leading to the repetition of the examination, increasing the radiation dose for the patient. We are trying to develop a model to evaluate the influence of drugs on the biodistribution of radiopharmaceuticals. Mitomycin-C is a drug that has been used as a component of many chemotherapeutic regimens. We have studied the effect of mitomycin-C on the biodistribution of the pyrophosphate labelled with technetium-99m (^{99m}Tc-PYP). Mitomycin was administered in three doses into Balb/c mice. One hour after the last dose ^{99m}Tc-PYP (7.4 MBq) was administered and after 0.5 hour the animals were sacrificed. The organs were isolated, the radioactivity determined and the percentages of radioactivity (%ATI) in each organ calculated. The results have shown that the % ATI of ^{99m}Tc-PYP: (i) has decreased in spleen, thymus, heart and brain; (ii) has increased in lung, liver and bone; (iii) has not altered in ovary, uterus, kidney, stomach and thyroid. These results can be justified by the metabolic process and/or the therapeutical effect of mitomycin-C and this alteration on the biodistribution of the studied radiopharmaceutical was capable to increase the radiation dose in some organs.

INTRODUCTION

Technetium-99m (^{99m}Tc) is the radionuclide of choice for imaging in nuclear medicine of its optimal physical and chemical characteristics. Nowadays, there are a large variety of molecules and cells that have been labeled with ^{99m}Tc (1).

The biodistribution or the pharmacokinetics of radiopharmaceuticals used in diagnostic imaging is grossly and recognizably altered by a wide variety of drugs and other treatment modalities, such as surgery and radiotherapy (2). The alterations on the biodistribution may be related to the chemotherapeutic drug interaction (3). A lack of knowledge of such altered biodistribution is important both in making diagnostic inferences from scans and in dosimetric considerations (4).

The ^{99m}Tc-pyrophosphate (^{99m}Tc-PYP) is used for bone, myocardial infarct imaging and also in red cell labeling for use in gated blood pool and gastrointestinal blood loss studies (1).

Mitomycin-C is a drug that has been used as a component of many chemotherapeutic regimens. This antibiotic was isolated from *Streptomices caespitosus* (5). This drug inhibits deoxyribonucleic acid (DNA) synthesis and cross-links DNA (6).

As the radiopharmaceuticals normally are fixed in specific targets and drugs can modify their biodistribution, we are trying to use these knowledges to develop a methodology to evaluate the mechanism of drug's toxicity. Furthermore, as a patient under chemotherapeutic can be submitted to a nuclear medicine procedure, we decided to study the effect of mitomycin-C on the biodistribution of the ^{99m}Tc-PYP in mice.

MATERIAL AND METHODS

Mitomycin-C (Bristol-Myers Squib, Brazil) solution (0.45mg) was administered by endovenous via into female isogenic Balb/c mice (n=15), in three doses with a 72 hrs interval. One hour after the last dose, 0.3mL of ^{99m}Tc-PYP (7.4 MBq) were injected by the same via. To prepare the ^{99m}Tc-PYP, ^{99m}Tc, as sodium pertechnetate eluted from ^{99}Mo/^{99m}Tc generator, was added to a kit of pyrophosphate (Laboratório de Radiofarmácia, INCa, Brazil). The radiochemical control was performed by ascendent chromatography, using paper Whatman n° 1 and 0.9% NaCl solution and acetone as mobile phases. The labeling efficiency was > 95% and the percentage of free pertechnetate was < 5%. After 0.5 h the animals were rapidly sacrificed. The organs were isolated (pancreas, thyroid, brain, thymus, ovary, uterus, spleen, kidney, heart, stomach, lung, liver and bone) and the radioactivity of the ^{99m}Tc-PYP counted in a well counter NaI(Tl) (Automatic Gamma Counter, 1272 Clinigamma, LKB, Wallac, Finland). The percentages of administered activity (%ATI) was determined for each organ. The results were compared with the control group, without mitomycin, and statistical analysis were performed (Wilcoxon test, $p < 0.05$).

RESULTS

Table 1 shows the relationship between the uptake of ^{99m}Tc-PYP in the group of the mice that was treated with mitomycin-C and control group (not treated). The analysis of the results reveals significant ($p<0.05$) reductions of the % ATI in spleen, thymus, heart and brain, increases of the % ATI in lung, liver and bone and no significant alteration of the % ATI in ovary, uterus, kidney, stomach and thyroid.

DISCUSSION

Radiopharmaceuticals have been in use for many years for the diagnosis and therapy of a wide variety of diseases (7). There is considerable evidence that the biodistribution of radiopharmaceuticals may be altered by a variety of drugs (8, 9). If unknown, such factor may lead to poor organ visualization, a requirement to repeat the procedure resulting in an unnecessary irradiations of organs (10, 11).

With the aim of developing an animal model to study the toxic effect of drugs, and due to a patient under chemoterapeutic treatment can be submitted to a nuclear medicine procedure, we decided to evaluate the effect of mitomycin-C on the biodistibution of the ^{99m}Tc-PYP. This radiopharmaceutical has been widely used both for myocardial infarct imaging and skeletal scintigraphy. The period of time between the administration of the radiopharmaceutical and the acquisition of the scintigraphic image can be different in the examinations. However, we have chosen the same period of time between the administration of the radiopharmaceutical and the sacrifice of the animals to compare the various radiopharmaceuticals and to try to establish an animal model to evaluate the drug interaction.

In our study, was observed that the treatment with mitomycin-C did not alter the uptake of ^{99m}Tc-PYP in ovary, uterus, kidney, stomach and thyroid. The scintigraphy with this radiopharmaceutical should be compromised due to the alterations in spleen, thymus, heart, brain, lung, liver and bone.

Some toxic effects after the injection of mitomycin-C have been reported. Bone marrow supression was the most frequent complication. Mitomycin induced thrombocytopenic in mice as a consequence of its bone toxicity (12). This fact would contribute to the alterations of the uptake of ^{99m}Tc-PYP in the bone after the use of mitomycin-C. It has already reported an alteration on the uptake of the ^{99m}Tc-MDP in bone with the same drug (13).

The uptake of ^{99m}Tc-PYP was modified in spleen. In other recent report about the effect of mitomycin-C on the %ATI/g of the ^{99m}Tc-MDP, was observed that mitomycin altered the spleen uptake (13).

Mitomycin cause interstitial pulmonary fibrosis (12). Due to its toxicity, mitomycin may cause abnormal pulmonary uptake of ^{99m}Tc-PYP.

Hepatic dysfunction is other mitomycin's complication. As it is reported that the mitomycin is rapidly inactivated in the microsomal fraction of the liver (5), this fact could contribute to increase the uptake of the radiopharmaceutical ^{99m}Tc-PYP in this organ.

None relate about thymus failure or cardiomyopathy. Moreover, it also may cardiotoxic when used in conjunction with doxorubicin (12).

The effects of this drug on the biodistribution of the studied radiopharmaceutical were statistically significant (Wilcoxon test, $p<0.05$) (14) and could be justified by the pharmacokinectic or the therapeutical effect of mitomycin C. As mitomycin's treatment altered ^{99m}Tc-radiopharmaceuticals uptake in some organs, any hot spots should be evaluated carefully to avoid a misdiagnosis. Moreover, we suggest to consider the drug interaction with radiopharmaceuticals and the possibility of the uptake of the radiotracer changes to non-target organs in the dosimetric calculations. The effect of this chemotherapeutic drug on the biodistribution of other ^{99m}Tc-radiopharmaceuticals are now in progress.

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Table 1. Effect of mitomycin-C on the biodistribution of ^{99m}Tc-PYP in mice: organs with alteration of the uptake.

	%ATI	
Organs	Control	Treated
Spleen	0.4252 ± 0.0676	0.1606 ± 0.0117
Thymus	0.1019 ± 0.0125	0.0580 ± 0.0055
Heart	0.7463 ± 0.0711	0.4902 ± 0.0856
Brain	0.4487 ± 0.0736	0.1997 ± 0.0194
Lung	0.3378 ± 0.0472	1.1478 ± 0.1519
Liver	1.9835 ± 0.6694	3.4778 ± 0.6783
Bone	0.0485 ± 0.0083	0.4084 ± 0.0507
Pancreas	0.0549 ± 0.0060	0.0357 ± 0.0045
Ovary	0.0312 ± 0.0058	0.0399 ± 0.0072
Uterus	0.1135 ± 0.0252	0.1036 ± 0.0135
Stomach	0.3196 ± 0.0462	0.2981 ± 0.0395
Kidney	2.2187 ± 0.5538	2.6650 ± 0.5556
Thyroid	0.0193 ± 0.0047	0.0195 ± 0.0037

The %ATI of ^{99m}Tc-PYP was calculated dividing the activity in each organ by the total activity administered and the results were compared with the control group. Statistical analysis were performed (Wilcoxon test, $p<0.05$). The values are averages ± standard deviations.

Cuestionario QA? Tain

LA PROTECCION RADIOLÓGICA DEL PACIENTE Y SU RELACION CON LA CAPACITACION Y EL CONTROL DE CALIDAD EN DIAGNOSTICO CON RAYOS X

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RESUMEN

El estudio se realizó en dos etapas, la primera en enero de 1997, antes de la aplicación de las nuevas normas oficiales mexicanas de protección radiológica y control de calidad en el diagnóstico médico con rayos X y la segunda después de dos años de vigencia de las normas. En la primer etapa se realizó un muestreo en 40 departamentos de radiología del área metropolitana de la Ciudad de México, obteniéndose 272 encuestas de personal médico y técnicos radiólogos. La segunda etapa terminó en enero de 2000, se evaluaron aspectos de seguridad radiológica y control de calidad en 33 departamentos de radiología diagnóstica con las mismas características de la primera etapa, pero se incluyó también médicos residentes de radiología y estudiantes técnicos, obteniéndose 257 encuestas. Al comparar los resultados de la primera etapa con la segunda se encuentra una mejoría en la capacitación en los aspectos de protección radiológica y control de calidad pero todavía los resultados son pobres. En la segunda etapa se incluyo un muestreo de control de calidad y se determinó que el 62% de las mediciones de kV_P están dentro del intervalo del ±5%, el 44% de las mediciones de tiempo están dentro del intervalo del ±5%. En la medición del punto focal el 64% de los equipos tienen un punto focal menor o igual a 1.2 mm. En las mediciones del rendimientos del tubo de rayos X monofásicos el 38% tienen un rendimiento dentro del intervalo que considera aceptable conforme a la norma. El 82% de los tubos de rayos X tienen una capa hemirreductora dentro del intervalo que establece la norma con una tendencia a incrementarse conforme aumenta el envejecimiento de los tubos. Debido a la falta del control de calidad en los servicios de radiología y de capacitación, los estudios repetidos al paciente se incrementan, así como estudios los estudios radiológicos no justificados.

Palabras Clave: Radiología diagnóstica, seguridad radiológica, control de calidad, capacitación.

ABSTRACT

The study was carried out in two stages, the first one in January of 1997, before the application of the new Mexican official norms of radiological protection and quality control in diagnostic radiology. The second stage was carried out two years after of application of the norms. In the first stage we were carried out a sampling in 40 departments of radiology of the metropolitan area of Mexico City, being obtained 272 surveys of personnel medical and technical radiologists. The second stage finished in January of 2000 in the same area. We were evaluated radiological safety and quality control aspects in 33 radiology departments, but in this stage were included medical radiology residents and technical students also, being obtained 257 questionnaires. The comparing the results of the first and second stages, we find an improvement in radiological protection and quality control training but the results are still poor. In the second stage a sampling of quality control were includes and the results were that 62% of the kV_P measures are inside of the 5%, 44% of the measures of time are inside of the 5%. In the measures of the focal point 64% of the X-ray units have a ≤ 1.2 mm focal point. In the measures of the rate (mR/mAs) of the X-ray tube with single phase generators 38% has a yield inside the interval that considers acceptable according to the norm. 82% of the X-ray tubes has a half layer ≤ 1.2 mm. Due to the lack of the control of quality in the radiology services and training, the repeated radiological studies to the patient are increased, as well as radiological studies not justified.

Key words: radiology diagnostic, radiological safety, quality control, training.

INTRODUCCION

La capacitación y actualización continua del personal médico y técnico de los departamentos de radiología en los aspectos de seguridad radiológica y control de calidad son una parte esencial de un proceso de certificación que permita garantizar a la población solicitante de estudios radiológicos que las instituciones tienen los recursos: humanos, materiales y tecnológicos, así como la capacidad física instalada para brindar una calidad excelente de atención médica. La calidad de la atención médica en radiología en México empieza a ser una preocupación no solo por la entrada en vigor de las nuevas normas sino porque en los últimos años la innovación tecnológica del equipamiento de rayos X, la demanda de imágenes con mayor probabilidad de un diagnóstico certero a menor costo y menor dosis, y los cambios en los métodos de enseñanza han modificado la forma de hacer radiología. Las normas actuales en seguridad radiológica y control de calidad son los primeros esfuerzos sólidos en México después de cien años de radiología, tendientes de evaluar y garantizar la calidad de los servicios de radiología actuales al menos en un primer nivel de control de calidad, aunque el costo inicial de mejorar la calidad de la atención médica en radiología podría ser alto en un principio, pero mas tarde los costos serían menores a los actuales, ya que en ausencia de normas los equipos de rayos X envejecieron muy rápidamente hasta llegar a convertirse muchos de ellos en no útiles para fines diagnósticos, algo similar sucedió con la capacitación del personal médico y técnico en seguridad radiológica y control de calidad, sin olvidar que también el personal que proporciona el servicio de mantenimiento preventivo y correctivo que esta en condiciones similares o peores. El propósito de éste estudio es tener una evaluación de la seguridad radiológica en radiología y el control de calidad durante los dos primeros años de la aplicación de las nuevas normas. En la primera etapa del estudio que se terminó en enero de 1997, justamente en el momento en que las nuevas Normas Oficiales Mexicanas entraban en vigor. En esta etapa se evaluaron aspectos relacionados con la seguridad radiológica en 40 departamentos de radiología de Institutos Nacionales de Salud, Hospitales de Especialidades y Hospitales Generales pertenecientes a la Secretaría de Salud, Instituto Mexicano del Seguro Social, Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado e instituciones privadas de la Ciudad de México y su área metropolitana. La información se obtuvo mediante un muestreo. El muestreo incluyó sólo al personal médico radiólogo y técnico, obteniéndose 272 encuestas. La segunda etapa del estudio se terminó en enero de 2000 y se evaluaron aspectos de la seguridad radiológica y el control de calidad en 33 departamentos de radiología diagnóstica con las mismas características de la primera etapa. El muestreo en esta segunda etapa incluyó personal médico radiólogo, técnicos titulados, técnicos no titulados, médicos residentes de radiología y estudiantes técnicos, obteniéndose 257 encuestas, se incluye en esta etapa un muestreo de varios parámetros de los equipos de rayos X, como la medición de kV, tiempo, rendimiento, capa hemirreductora y punto focal en equipo convencionales distribuidos en toda la república mexicana.

MATERIALES Y METODOS

En la primera etapa del estudio terminada en enero de 1997, se evaluaron los aspectos de seguridad radiológica mediante la aplicación de una encuesta a personal de 40 departamentos de radiología, 37 públicos y 3 privados, pertenecientes a Institutos Nacionales de Salud, Hospitales de Especialidades y Hospitales Generales pertenecientes a la Secretaría de Salud, Instituto Mexicano del Seguro Social, Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado e instituciones privadas del área metropolitana de la Ciudad de México. La información se obtuvo mediante un muestreo en dos etapas con la aplicación de una encuesta diseñada con 35 variables dicotómicas que se aplico al personal médico y técnico de radiología, obteniéndose 272 encuestas. La segunda parte del estudio se terminó en enero de 2000, se evaluaron los aspectos de la seguridad radiológica en 33 departamentos de radiología diagnóstica, 17 públicos y 16 privados, la encuesta aplicada consistió de 46 variables dicotómicas con las mismas características de la primera parte y se obtuvieron 257 encuestas.

Los criterios para seleccionar y procesar las encuestas contestadas fueron: 1. Se procesaron todas las encuestas que fueron contestadas en el momento de su aplicación sin consultar literatura ni a otros colegas, 2. Sólo se consideró la primera encuesta contestada cuando el personal entrevistado trabajaba en dos Instituciones

seleccionadas. La base de datos obtenida de las encuestas contestadas fueron procesadas con métodos estadísticos entre ellos el modelo logístico de regresión. El modelo logístico usado fue:

$$Log\left(\frac{P_i}{1-P_i}\right)=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_1*X_2$$

Las β_i son los parámetros del modelo y se estiman a partir de los valores observados y representan la magnitud del efecto de la variable predictora en la variable de respuesta. Las variables de respuesta se evalúan en función de las variables X_1 y X_2. El término β_3 representa la interacción entre las variables X_1 y X_2, que en este modelo será considerada como una medida de asociación. La población en estudio en relación al control de calidad fueron los equipos de rayos X instalados en la República Mexicana y en el caso de la seguridad la población en estudio fueron los especialistas en radiología, médicos especialistas, médicos residentes, técnicos titulados y técnicos no titulados y estudiantes técnicos que laboran en los departamentos de radiología del área metropolitana de la Ciudad de México. Los equipos de rayos X que participaron en este estudio habían tenido mantenimiento preventivo y correctivo sin control de calidad, se incluyeron equipos monofásicos, trifásicos, alta frecuencia y potencial constante. Con la verificación se inició el control de calidad. El muestreo de control de calidad tuvo una sola etapa realizada durante 1999, con la información generada se obtuvieron histogramas y gráficas de barras mostrando las distribuciones de las variables evaluadas.

RESULTADOS

Seguridad Radiológica

En la primera etapa del estudio se obtuvieron los siguientes resultados generales: las variables de respuesta son independientes del tipo de personal, esto es, no hay diferencia significativa en la frecuencia de respuestas entre el personal médico y técnico, los mismos resultados se obtienen para miembros y no miembros de una asociación profesional y para ambos turnos laborales con una $p < 0.05$. Más del 50% del personal ocupacionalmente expuesto de radiología usa dosímetro, pero sólo el 17% de ellos conocen los reportes de dosis. El 16% del personal considera que el dosímetro les protege contra la radiación y sólo el 17% conoce la dosis máxima permisible anual para efectos estocásticos. El 26% del personal tiene expediente médico pero menos de la mitad de ellos conoce los resultados de los exámenes médicos. Menos del 1% conocen los efectos biológicos de la radiación sobre todo considerando que el 73% del personal tiene más de 3 años e experiencia. Sólo el 21% del personal conoce los principios de protección radiológica y el 14% conoce que son los rayos X. Del personal con experiencia mayor a 3 años y que usa dosímetro, el 88% son técnicos y el 12% médicos. Del personal que tiene más de tres años de experiencia y conoce los principios de protección radiológica, el 86% son técnicos y el 14% son médicos, lo mismo sucede con el personal con una experiencia menor a 3 años. La afiliación a las asociaciones profesionales de radiología es 6.2 veces a favor del médico radiólogo con relación al técnico.

La segunda etapa del estudio incluyó personal médico radiólogo, técnicos, médicos residentes de radiología y estudiantes técnicos, cuya distribución se muestra en la figura 1.

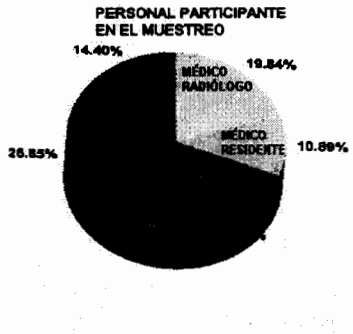

Figura 1, Personal participante en la segunda etapa del estudio.

Como resultado del muestreo se encontró que en la segunda etapa si hay diferencia significativa en la frecuencia respuestas entre el personal médico y técnico, los mismos resultados se obtienen para miembros y no miembros de una asociación profesional en radiología con una $p < 0.05$. Del personal encuestado el 71% pertenecen a instituciones públicas, el 68% tiene más de 2 años de experiencia en radiología, el 37% ha participado en cursos de seguridad radiológica, el 75% conoce el contenido de las normas, el 71% son miembros activos de una asociación profesional de radiología, el 32% tiene expediente médico, el 42% tiene dosimetría personal, el 26% conocen el manual de seguridad radiológica de su departamento y el 35% conocen los principios de protección radiológica. El 20% de la muestra son médicos radiólogos, de los cuales el 81% están certificados por el consejo de radiología, el 55% son miembros de una asociación profesional de radiología, el 19% de ellos tiene más de dos años de experiencia, el 33% conoce al menos 3 pruebas de control de calidad en los equipos de rayos X convencionales y el 31% conoce los principios de protección radiológica. El 55% de la muestra son técnicos radiólogos, de los cuales el 60% están titulados, el 42% son miembros de una asociación profesional en radiología, el 60% tiene más de 2 años de experiencia, el 31% conoce al menos 3 pruebas de control de calidad en los equipos de rayos X y el 60% conoce los principios de protección radiológica. El conocimiento sobre las normas en dos años del 20% al 80%. Solo el 35% del personal conoce los principios de protección radiológica y entre el 15% y 18% del personal conoce que son los efectos biológicos de la radiación. La carencia de los principios de protección radiológica y el desconocimiento de los efectos biológicos de la radiación puede ocasionar un exceso de confianza o un temor no justificado a la radiación. En radiología diagnóstica no podemos separar los aspectos de seguridad radiológica del control de calidad, ya que la seguridad radiológica del personal y del paciente va a depender también del programa control de calidad que tenga cada departamento de radiología. el 33.3 % del personal de médicos radiólogos conocen al menos tres pruebas de control de calidad en equipos de rayos X convencionales. El efecto que tienen las asociaciones profesionales de radiología en la capacitación de sus miembros, es 2:1 a favor de los miembros de una asociación.

Control de Calidad

El muestreo del control de calidad se realizó durante el año de 1999. En la evaluación de la exactitud de los kV_P participaron 70 equipos de rayos X distribuidos en toda la República Mexicana de las diferentes marcas, incluyendo monofásicos, trifásicos, alta frecuencia y potencial constante, estos dos últimos con tecnología de microprocesadores son los que presentan una mayor exactitud en los kV_P en el rango medido de 60 a 100 kV_P.
Se encontró el 62% de las mediciones de kV_P están dentro del intervalo del ± 5%, lo cual es razonable debido a que fueron las primeras verificaciones de control de calidad que se realizarón a los equipos de rayos X posiblemente desde su instalación. El 44% de las mediciones de tiempo están dentro del intervalo del ±5%.
En la medición del punto focal grueso participaron 45 equipos de rayos X, de los cuales el 64% tienen un punto focal menor o igual a 1.2 mm. En la medición del punto focal fino participaron 27 equipos de rayos X y el 81% tienen un punto focal menor o igual a 0.8 mm. En las mediciones del rendimientos del tubo de rayos X participaron 21 equipos de rayos X monofásicos y el 38% tienen un rendimiento dentro del intervalo que considera aceptable conforme a la norma vigente (4 – 6 mR/mAs). Solo el 43% de los equipos trifásicos, alta frecuencia y potencial constante se encuentran dentro del intervalo que establece la norma (6 – 8 mR/mAs). El 82% de los tubos de rayos X tienen una capa hemirreductora dentro del intervalo que establece la norma (> 2.3 mm Al), con una tendencia a incrementarse conforme aumenta el envejecimiento de los tubos.

CONCLUSIONES Y DISCUSION

Como resultado de la aplicación y cumplimiento de las normas de seguridad radiológica y control de calidad en el diagnóstico médico con rayos X durante los dos primeros años, se muestran avances y tendencias a mejorar la seguridad radiológica y el control de calidad, aunque los resultados son todavía pobres considerando que los resultados del muestreo en seguridad radiológica son del área metropolitana de la ciudad de México donde el personal tiene un mayor acceso a la capacitación y la actualización, se espera que si se realiza un muestreo en toda la república mexicana los resultados posiblemente sean que el personal esta menos capacitado

y actualizado. El muestreo de control de calidad se encontró que la mayoría de los ingenieros de servicios no cuentan con capacitación en control de calidad.

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Nuestro agradecimiento a los alumnos del TID de la Universidad Autónoma Metropolitana, Xochimilco: Claudia E. Cardenas V., Ma. Edith Rojas l, Mirna J. Hernández P., Fernando Avila T., Francisco Javier Contreras S., Nancy Mercedes Fernández P., Diana Erendira Flores V., Armando García A., Osvaldo Gutiérrez M., Marco Antonio López A., Jorge Octavio Navarrete C., María de los Angeles Olalde J., Mónica Ramírez M., Juan Pablo Sánchez E., Denys Ernestina Suárez P., José Luis Ugalde U., Emmanuel Valenzuela J., por su colaboración. Agradecemos a las instituciones públicas y privadas que permitieron la realización de este estudio.

INTERNA[T]ON THE RADIOLOGICAL PATIENTS

in

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

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ASSESSMENT OF RADIATION DOSES TO THE PATIENTS IN MEDICAL X-RAY DIAGNOSIS

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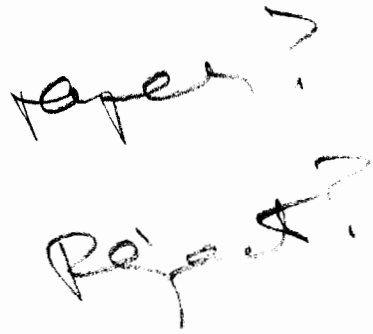
It is well-known fact that the radiation doses from diagnostic radiology are the largest contribution to the collective dose from all man-made sources of radiation. So, for example, its contribution to a collective dose of the population of Russian Federation reached 40%. Thus more than 95 % of this contribution was stipulated by X-ray diagnostic examinations of the patients. From this, it is obvious that diagnostic radiology should be of major concern for radiation protection and that, consequently, the guidelines established by the ICRP for occupational radiation protection should be applied also to diagnostic radiology as far as possible (justification, optimisation, limitation). Key link for the solution of these problems is the information about patient doses in view of parameters of the concrete radiological procedure. Besides according to the Federal Law of Russian Federation "About radiation safety of the population" the citizen has the right on deriving of the information as about the value of a dose of a medical exposure, and value of additional risk connected to such exposure. In the present work using "fast" calculation methods and computational models of human body of various age numerous studies concerning an evaluation of organ doses and effective dose to the patients undergoing X-ray examinations were performed. The values of an effective dose for the patients of various age for most mass X-ray examinations in Russia are represented. The influence of exposure condition as, e.g., tube voltage, filtration, field size and location, focus-to-skin distance, on organ and effective dose of patient of various age were studied with the purpose of optimisation in X-ray diagnosis.



ESTIMATION OF AN EFFECTIVE DOSE FOR THE PATIENTS UNDERGOING X-RAY EXAMINATION WITH THE HELP OF PHANTOM EXPERIMENTS

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In the report the results of six phantom experiments, fulfilled with the purpose of definition of an effective dose for the patients of different age undergoing X-ray examination are represented. In experiments have used physical phantoms of the adult man (Alderson Rando) and child of five years ("ATOM ltd" production). Doses inside the phantoms were measured using TL-detectors (TLD-100, Harshaw). In experiments for both phantoms imitated chest and urography examinations with parameters typical for their running in Russia and Sweden. The values of organ and effective doses are represented. The experimental values compared to the relevant calculation values.

OK D

MEDICAL EXPOSURE IN RUSSIA

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Recently there have been considerable changes in radiology, which is because of coming to a new form of property, reforms of health services and crisis in the society. Big area, bad means of communication and low density of population in most regions of the country should be also mentioned among the factors, influencing the level of both health protection and radiology services. Al this factors don't allow to create an effective radiology system in a short time. Meanwhile the main nearest task of radiology is the integration and optimization of all means of visualization on the base of solving fundamental problems of health protection according to the Federal program, normative acts and decrees of the government. In this connection it seemed to be an urgent task to estimate various aspects of radiology activity of Russian Health in the dynamics for the recent period of time. The data of the state statistics are to be used to cope with this task. These data on the base of the computer program "Region" the quantity indices of various visualization methods used in Russia and the doses of exposure of the population have been estimated and the reference book "Medical irradiation of the population in Russia.1980-1997 years" has been published.
It turned out that the average annual number of X-ray examinations per thousand population in Russia before 1988 year was constantly up to 1600. And only then because of Chernobyl accident its increase stopped and its gradual decline began (table 1). Such high frequency of the examinations was caused mainly by the large scales of mass preventive fotofluorography (more than 40%), held for early tuberculosis exposure.

Table 1 **The dynamics of medical radiation exposure in Russia**

Index	Years						
	1965	1970	1975	1980	1985	1990	1997
X-Ray Examinations							
Number examinations per 1000 population	1120	1204	1332	1488	1682	1177	1230
Contribution,%							
Fluoroscopy	47	40	27	13	7	5,5	5
Radiography	27	27	36	49	43	54	54
Photofluorography	26	33	37	38	50	41	39
Dental	*	*	*	*	4,7	7,0	7,8
Mammography	*	*	*	0,6	0,4	0,3	0,4
CT	*	*	*	*	*	*	0,5
Chest	81	76	71	64	62	51	45
Digestive organs	6	8	10	13	14	12	6
Skeleton	10	12	14	18	19	24	36
Other	3	4	5	5	7	13	13
Nuclear medicine							
Number examinations per 1000 population	*	*	*	9,0	10,5	15,3	12,6
Ultrasound diagnostic							
Number examinations per 1000 population	*	*	*	*	*	80	270
Radiation therapy							
Number examinations per 1000 population	*	*	*	0,98	0,99	1,57	1,66

* the data are not provided by statistical form

It was as a result of reorganization of fluorographic examination system started in the late 80-s early 90-s that this pernicious tendency was overcome and the number of fluorography was reduced almost twice from 90 to 56 millions a year, which considerably contributed to reducing the exposure. Unfortunitely as a result of it, the rate of tuberculosis has increased, which led to the recommencement of mass fluorographic screening in former or ever larger scales.

Recently the number examinations per 1000 population has reduced to 1200. The specific feature of modern X-ray diagnostic is its competing with new non-radiation Examinations, in particular with ultrasound and endoscopic ones. These methods are very efficient and recently have been developing very actively. Nevertheless, the classical radiology is not going to surrender and it spite of some reducement of examinations amount it is still the leader among all ways of visualization. The structure of X-ray examinations has changed considerably during the last decades: the number of the most dose-making examinations has become 8 times less, the number

of the most informative and the least dose-making radiography examinations has twice, and only the amount of fotofluorography examinations , including screening, has declined inconsiderably.

Among all X-ray examinations the maximum quantity is still that of chest and skeleton. The amount of X-ray examinations is equal for male and female parts of population, 53,7% and 46,3% accordingly . Speaking of the age of the examined , it should be noted that the most part of X-ray examinations is held among middle-aged and especially elderly people. Children's contribution is inconsiderable. This correlation has been stable for the recent period of time.

A detailed study of X-ray examinations shows that the main contribution to it is made by diagnostics and screening of lung, stomach examinations as well as examinations of skull and extremity. Recently there has increased the number of special X-ray examinations among which are angiography and intervention methods. They are the most informative, but at the same time they are accompanied by very high dose, including the influence on skin.

Considerably yielding to traditional X-ray examinations are dental and mammography. Their contribution to the general number of X-ray examinations is inconsiderably, inspite of their importance and significance. However the speed of the development of this methods is rather high.

The most rapid is the development of ultrasound diagnostic and computed tomography. Presently magnetic-resonance tomography (MRT) has joined them, positron-emission tomography (PET) is coming up and the future radiology belongs to these new methods.

There are 4150 physicians, 103 radiologist and 235 X-ray unit for 1 million population in Russia. On one equipment 5260 examinations a year are held. An average X-ray examinations for 1 radiologist is 12385 a year.

Recently an average effective dose from X-ray examinations has had a 20% decline from 1,0 to 0,8 mSv which is caused by changed in the structure of X-ray examinations (table 2).

firstly the whole range of equipment for full-scale examinations, including angiographic, CT, MRT, PET etc., and secondary to introduce new methods of radiology, including intervention ones.

The exceptional significance of medical exposure is detriment not only by the level of its contribution to a population dose, but also by possessing the most considerable, economically not burdensome reserves to reduce this contribution and consequently to provide a considerable decline of the whole dose on population from all the sources of radiation.

RESULTS AND CONSEQUENCES OF MEDICAL EXPOSURE LIMITATION AFTER CHERNOBYL ACCIDENT

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Counter measures for prevention of public over exposure after accident include optimization of medical radiological procedures.

Applying the conventional methodology of reducing medical exposure such as the improvement of equipment, management, education of personal and strict selection of patients for radiological procedures resulted in reduction of individual effective dose more than 3 times and population dose up to 20%. The results are presented in table.

Table

Reducing annual individual effective dose from medical exposure in Briansk region after Chernobyl accident (mSv)

Region	Year								
	1985	1986	1987	1988	1989	1990	1991	1992	1993
Novozybkov	1,11	0,85	0,67	0,18	0,12	0,09	0,11	0,25	0,30
Klintzy	0,94	1,03	0,38	0,69	0,54	0,20	0,72	0,30	0,25
Klimov	1,06	0,84	0,60	0,56	0,23	0,20	0,20	0,51	0,48
Krasnogorsk	0,93	0,79	0,65	0,42	0,21	0,11	0,31	0,13	0,15
Zlynka	0,57	0,38	0,37	0,20	0,12	0,29	0,52	0,22	0,28
All	**1,08**	**0,79**	**0,55**	**0,41**	**0,31**	**0,18**	**0,28**	**0,30**	**0,29**

The must effective way to reduce public medical exposure was extensive education and training of personnel based of WHO publications, reducing the unnecesary procedures with strict justifications.

The additional rules and guidelines for reducing anaban of radiography in favor of fluoroscopy, limitation of mass fluorography depending on relatively low medicine of tuberculosis in 80s. The effectiveness of the measures is demonstrated in the Table. In comparision to the average individual effective dose from medical exposure in Russia - 1 mSv the averaged dose in Briansk region is up to 0,3 level.

Due to the optimization of medical exposure with limitation and decrease of medical radiological procedures the increase in morbidity might be observed for some specific diseases, e.g. tuberculosis, cancer, chronic lung diseases a. oth. The data obtained indicate that such a situation might be prevented by the balanced optimization procedures (relevant).

PATIENT DOSE OPTIMISATION IN CARDIOLOGY DURING FLUOROSCOPY EXAMINATIONS

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Abstract

Data from 1200 cardiac examinations recorded during the past ten months have been analysed. The DAP's obtained for most of the examinations are comparable to the published data. Moreover, an excellent correlation has been found between the high DAP value and the experience of the operator. DAP measurements for "high dose examinations" are getting mandatory in several countries, and medical physicists should help the physicians to interpret these measurements in order to improve the safety of the ionising radiation use. In our centre it appeared that for their first examinations physicians should be more closely guided by seniors.

Introduction

Several studies have shown that during cardiac procedures carried out under fluoroscopy, such as coronary angiography or percutaneous transluminal coronary angioplasty (PTCA), the amount of radiation delivered to the patient could be relatively high. It is therefore important to monitor patient dose so that radiologists or cardiologists can make an objective assessment of the justification of the procedure. The most convenient quantities to monitor patient dose are the fluoroscopy time and the dose-area product (DAP). The main limitation of the DAP quantity is that it cannot give directly a precise information concerning the determinist risk associated with a procedure. However, it can be used to set warning and action levels to avoid skin injuries as demonstrated by Bibbo et al. [1]. The other limitation of the DAP information is that there is a lack of reference or guidance values published in the literature concerning cardiac procedures. Thus, even if the DAP information is recorded in the patient files, it remains very difficult to estimate if a DAP delivered to a patient for a specific procedure was expectable or high.

In such a context it was decided in our hospital to record during almost one year, the total dose area product (DAP), the fluoroscopy time, the examination description and the operator references. The goals of the study were the followings :

- Assess the third quartile of the DAP for the most common examinations and compare them to the available data in order to verify the good practice of operators;
- Verify if a lack of training existed among the operators;
- Give a set of DAP values to the operators to enable them to assess if the DAP they deliver can be justified by the simplicity or complexity of the procedure;
- Propose a warning level to the operators.

Material and method

The examinations were performed using two units (advantix LC+ and LCLP, GE Medical Systems, Milwaukee, Wis) of the hospital which are equipped with a DAP-meter (PTW, Freiburg, Germany) traceable to the Swiss Federal Office of Metrology. The total DAP, the fluoroscopy time, the examination description and the operator references were systematically recorded by the radiographers at the end of each procedure for about 1200 patients.

Results and discussion

The number of examinations, the medians, 3rd quartiles and ranges of the DAP values and fluoroscopy times are reported in Table 1. The data have not been corrected according to patient size, since the goal of the study was to define a set of reference DAP values for the operators which could be directly compared with the data available on the DAP-meters at the end of the procedure, without any data processing. The third quartile obtained for the coronary angiographies and angioplasties (PTCA) are comparable to the ones published in the literature.

Table 1 - DAP and fluoroscopy times recorded during the survey

procedure	proced. #	DAP_{median}	DAP_{3rd}	range	$time_{median}$	$time_{3rd}$	range
Angiocardiography	25	15.3	22.5	4 - 102	13	17	4 - 23
L and R catheterisms + coronary angiography	95	66	125	13 - 286	10	17	3 - 59
PTCA	210	60	80	10 - 272	9	16	4 - 70
Coronary & Ventriculo. angiography	780	49	84	3 - 702	7	12	1.5 - 65
Left vent. coronary angiography	35	59	66	10 - 203	8	11	1.5 - 40
Coronary angiography	35	40	70	5 - 390	6	22	3 - 50
Cardiac biospsy	20	4.7	7.6	2 - 23	1	1.7	0.5 - 6

The angiocardiography examination is performed most of the time on young patients and the DAP's are generally quite low in spite of relatively long fluoroscopy times. Thus, no correlation between the DAP values and the fluoroscopy times have been evidenced between these two quantities (r=0.08). However, an excellent correlation appeared between the DAP values and the age of the patients (r = 0.88). This result clearly shows that for young patients DAP guidance values should be weighted with the age of the patient.

As opposed to the angiocardiography procedures, an excellent correlation between the DAP and the fluoroscopy times have been systematically obtained for the other procedures which were always performed on adults ($r = 0.88 \pm 0.05$). Thus, for adults it seems that guidance levels can be expressed either in term of fluoroscopy time or DAP value.

Figure 1 present the distribution of the DAP percentiles concerning the coronary-ventriculo angiography examinations per operator. The reference DAP proposed in our centre is also indicated on the figure by a thick line. From this figure it appears clearly that all the operators having more than 5 years of experience, have their DAP third quartile below or close to the proposed reference value, and that even if they often involved with more difficult cases. The data concerning younger cardiologists are presented on the ride side of the figure. All of them are clearly above the proposed reference value.

The DAP data should not only be used to verify if the dose delivered to the patient after a procedure could be expected, but should be also used during the procedure to indicate if one gets close to the deterministic risk associated with fluoroscopy. The difficulties in using DAP to evaluate skin dose is that the irradiated area of the skin change size and location during the procedure. Thus, it is not possible to evaluate a precise entrance dose from a DAP measured during an interventional procedure. Nevertheless, one can adopt a conservative approach in order to define warning and action levels to avoid skin injuries. Taking into account the diameter of the amplifier which is the most frequently used during these procedures (ø 23 cm), and the focal spot to skin of the patient (50 cm when the distance from the focal spot to the amplifier is 90 cm), an averaged area of 130 cm^2 has been obtained. Taking this averaged irradiated area into account and considering that the tube does not move during the procedure, a warning level of 130 $Gy.cm^2$ has been proposed to our staff performing cardiac procedures. This would correspond to an entrance dose of 1 Gy. In spite of being quite conservative, this level is however lower than the DAP's third quartile measured during this survey. Above the warning level proposed here, a senior operator should take over. He should try to work in the lowest dose mode available and distribute the dose by changing the tube angles.

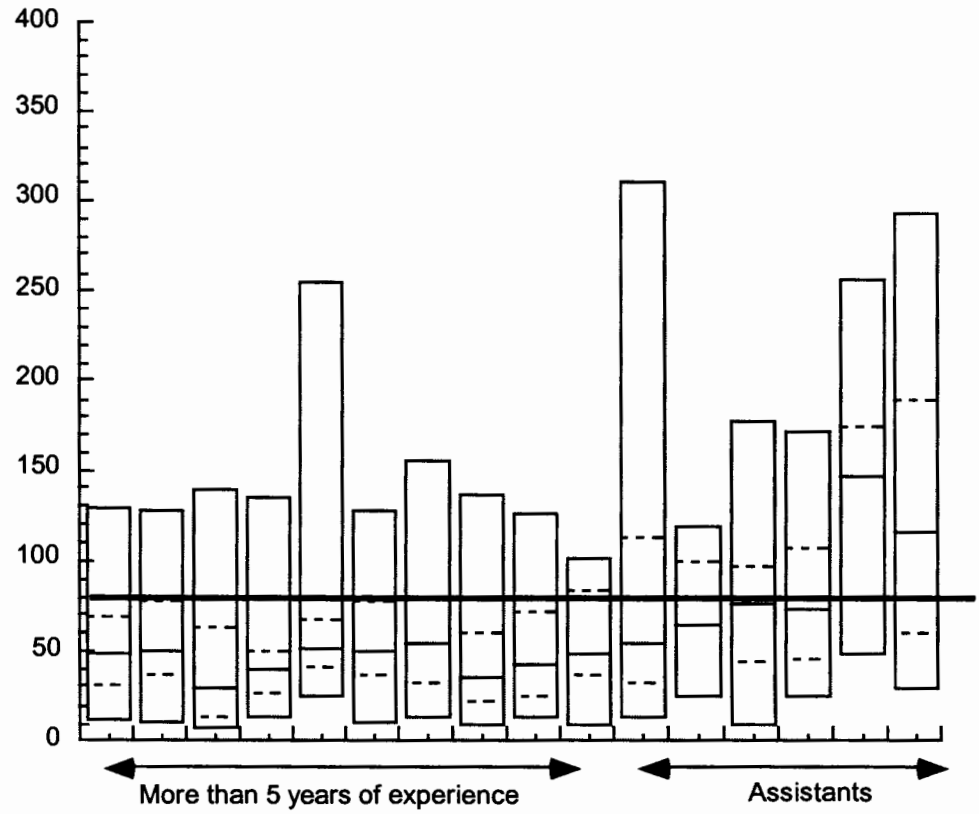

Figure 1 - percentiles of the coronaro-ventricolu angiography per operator

Conclusion

The systematic recording of the DAP and fluoroscopy times has been integrated in our quality assurance programme. It has enable us to verify if the doses delivered during the most common cardiac examinations were comparable to the data available in the literature. This study has also enabled our medical staff to take advantage of DAP data displayed during the procedures, in particular to avoid skin burns. Finally, a change in the training of our new medical staff is being implemented with an emphasis on the optimal use of the fluoroscopy units.

Reference

[1] Bibbo, G., Balman, D.. Calculation ofentrance exposed area from recorded images in cardiac diagnostic and interventional procedures. Proceedingsof the 10th International Radiation Protection Association Congress, Hiroshima-Japan, 11-14 may 2000.

OK Pedi-Dose of CT

INTRODUCTION OF GUIDANCE DOSE LEVELS IN PAEDIATRICS CT

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Abstract

The purpose of this work is to present a methodology in order to define reference levels for chest or abdominal CT examinations performed on children. For children aged from 0 to 6 the $CTDI_w$ measured in the head test object (i.e. ø 16 cm) should be used as a dose indicator. For children older than 12 years old the $CTDI_w$ measured in the body test object (i.e. 32 cm) should be used as a dose indicator. For children aged between 6 to 12 we propose to use an intermediate $CTDI_w$ in order to avoid an over or underestimation of the dose delivered in the slices. Finally a set of dose length products (DLP) measured in our centre for standard abdominal acquisitions will be given.

Introduction

In conventional radiology the use of a screen film system as a detector assures, if the films are correctly processed, that the dose delivered to the patient is within a predictable limit. As a matter of fact, the latitude of exposure available on a screen film system is relatively limited (typically one order of magnitude) and a constant exposure is required to produce a satisfactory film density. On the contrary, digital detectors are characterised by a wide latitude of exposure (typically 3 to 4 orders of magnitude). This property eliminates the typical relationship between the radiation exposure and the image optical density. With digital detectors the only parameter which will be linked to the dose is the image noise. Thus, radiation protection of the patient have to be emphasised with the use of digital detector

CT examinations represent about 5 % of all the radiological examinations performed on adults. However, its contribution to the effective dose delivered in radiology is within 27 to 35 % [1-2]. To avoid an uncontrolled increase of the CT contribution on the effective dose delivered by medical applications a recommendation has been published by the CEC [3]. This recommendation indicates together with a reference dose some image quality requirements for the most common examinations. Manufacturers are now offering on their units the possibility to get a dose indicator corresponding to the examination performed on each patient (i.e. indication of the $CTDI_w$ and the DLP). Thus, it seems now relatively easy for the radiological community to assess the dose delivered to the patient for CT examinations. Those can be compared to the reference levels in order to begin an optimisation process.

The use of CT in paediatrics is more limited than for adults and at the present time there is no recommendation to verify if the radiological constants used (kV, mA, pitch ...) are adequate.

Very often, the mA reduction (if any) performed by radiographers to scan children has no strong scientific background.

For adults, two $CTDI_w$ has been defined : one to be applied for head of neck examinations ($CTDI_w$ head measured with a test object of 16 cm in diameter) and one to be applied to chest or abdominal examinations ($CTDI_w$ body measured with a test object of 32 cm in diameter). In paediatrics it seems that these two quantities are not sufficient to introduce reference levels.

In this paper we will propose an intermediate $CTDI_w$, which can be derived from the standard $CTDI_w$ used for adults. This $CTDI_w$ will be based on the variation of an equivalent abdomen diameter with age. This concept will be used to present the doses delivered for abdominal examinations in our centre. These results will be given for a single-slice CT (SSCT) and a multi-slice CT (MSCT).

Material and method

The SSCT used in this study is the HiSpeed CT/i system (GE Medical Systems, Milwaukee, Wis) and the MSCT used in this study is the LightSpeed QX/i (GE Medical Systems, Milwaukee, Wis) which allows the sampling of four slices per tube rotation. The CT units involved in this study calculates and displays the Dose-Length Product (DLP) corresponding to the acquisition protocol used. The indicated $CTDI_W$ and DLP values were verified.

Equivalent abdominal diameters have been estimated by using weight and height tables corresponding to the paediatric population of Switzerland. To begin with, a PA abdominal thickness has been estimated by means of the relationship established for fluoroscopy examination by Leug et al. [4] : PA thickness = 2 [Weight /(1000 x π x Height)]. Since the abdomen section is closer to an ellipse than a circle an equivalent CT diameter has been proposed by simply multiplying the PA thickness described previously by 1.5. Using these data an intermediate $CTDI_W$ has been calculated for children aged between 6 to 12 years.

Results and discussion

Figure 1 presents the variation of the proposed equivalent CT diameter in function of age. These data are based on the 3 percentile of the weights and heights distributions mentioned previously. It appears that the use of the $CTDI_W$ measured with the head test object as a dose indicator is adequate for very young children (i.e. 0 to 6 years old). One can notice that a diameter of 32 cm is obtained for the age of 18. Thus, the $CTDI_W$ measured with the body test object appears to be a rather good dose indicator for that particular age. In order to simplify the approach we propose to use this dose indicator for patient older than 12. For children aged between 6 to 12 the use of a $CTDI_W$ measured in a body test object will underestimate the dose delivered in a slice, whereas the use of a $CTDI_W$ measured in a head test object will overestimate that dose. In order to find a compromise we propose to use a mean $CTDI_W$: average of the head and body $CTDI_W$.

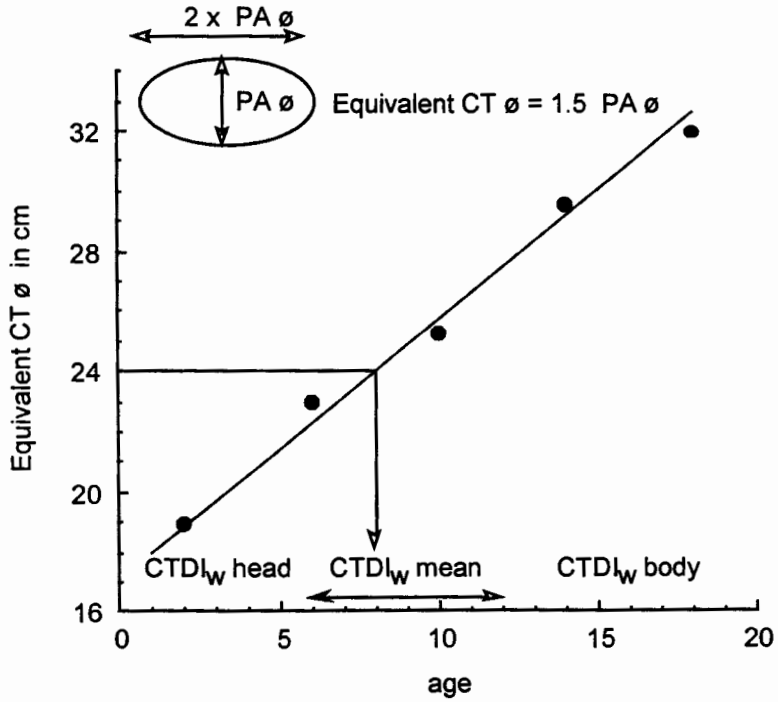

Figure 1 - Equivalent CT diameter versus to age

The head and body $CTDI_w$'s have been measured and two CT units at different kilovolts. Using these data a mean CTDIw have been calculated for both units. The results are summarised in Table 1.

Using the data presented in Table 1 and the acquisition protocols used in our centre the doses delivered per slice (i.e. $CTDI_w$ divided by the pitch value) have been calculated. For each category of ages an average scan length has been estimated allowing the DLP calculation. These data are summarised in Table 2.

Table 1- $CTDI_w$ data of the CT used in this study

	$CTDI_w$ (mGy/mAs)	100 kV	120 kV	140 kV
SSCT	head	0.07	0.10	0.14
	mean	0.06	0.08	0.11
	body	0.05	0.06	0.08
MSCT	head	0.17	0.26	0.36
	mean	0.26	0.20	0.27
	body	0.09	0.13	0.19

Table 2 - Dose estimators comparison between the two CT used in this study

Unit	Age	Acquisition protocol *	Dose per slice (mGy)	DLP (mGy.cm)
SSCT	> 12	120 kV - 290 mA - 1 s - p= 1.2	14.5	32 cm** -> 464
	6 - 12	120 kV - 230 mA - 1 s - p= 1.2	15.3	22 cm -> 337
	1 - 6	120 kV - 190 mA - 1 s - p= 1.0	19.0	17 cm -> 323
	0 - 1	120 kV - 170 mA - 1 s - p= 1.0	17.0	11 cm -> 187
SSCT	> 12	120 kV - 200 mA - 0.8 s - p= 1.5	13.9	32 cm -> 445
	6 - 12	120 kV - 140 mA - 0.8 s - p= 1.5	14.9	22 cm -> 328
	1 - 6	120 kV - 120 mA - 0.8 s - p= 1.5	16.7	17 cm -> 284
	0 - 1	120 kV - 100 mA - 0.8 s - p= 1.5	13.9	11 cm -> 153

*) the numbers correspond to the tube high voltage, tube current, time of one tube rotation and pitch

**) average scan length

The data presented in this study show that for the standard abdominal acquisition presented here the dose per slice as defined remains almost constant with the age of the patient (i.e. 15 mGy). From our data it appears that the following DLP reference values could be applied : [0 - < 1 year] : 170 mGy.cm ; [1 - < 6 years] : 300 mGy.cm; [6 - < 12 years] : 350 mGy.cm ; and [12 - <18 years] : 450 mGy.cm.

The same methodology was applied to the examinations of the chest. The results show that a significant lower dose delivered in the slice could be used (i.e. 7 mGy). This particular situation is due to the lower X-ray absorption of the tissue.

Conclusion

DLP's have been proposed for the standard abdominal examinations in paediatrics CT. The acquisition protocols presented here are considered optimised by our radiographer, since a dose reduction would lead to a drastic image quality reduction. Using these data, the image quality obtained is accepted by our radiologists. It is interesting to notice that the dose per slice remains almost constant for a wide variation of CT equivalent diameter. This result should now be integrated in a simulation in order to verify if a better solution could be reached.

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AN ACCIDENT IN BRACHYTHERAPY MACHINE

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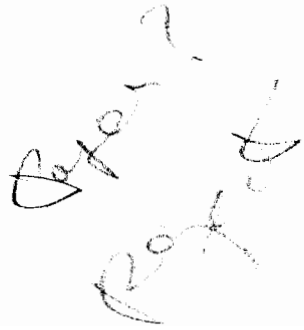
A proto-type of a remote-control brachytherapy unit was installed in our hospital in April 1989. The unit has 5 channels with 5 Ir-192 sources, each source contains about 400mCi of Ir-192. It was check every week. After checking, the panel showed that one source could not return to the proper position automatically so the source was returned manually. The factory was asked to come to check the unit but due to some reason they could not come in time. Unfortunately the survey meter was broken. Meanwhile, an urgent treatment was needed, so a patient was treated by using the other 4 sources. The next day, by using another survey meter and a source was found outside the unit due to the breakage of the source and the cable. The patient and the technician were followed for sometime and no adverse reaction was found. It might have been due to the low energy and small dose delivered to the patient and technician. Since then this unit has not been used anymore. Every brachytherapy treatment room is equipped with an alarm survey meter .



OK CT of fluoro

IAEA-CN-85-141

RADIATION DOSE AND QUALITY CONTROL IN FLUOROSCOPY AND COMPUTED TOMOGRAPHY SCANNING

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Abstract

The total of 16 fluoroscopic units was selected in this study. Basic QC tests were performed on all the units with RMI QC kit and a TRI SOLIDOSE 400 dosimeter. 20 patients for 4 fluoroscopic units were selected for barium meal (upper GI) and the doses were measured using two calibrated DAP meters (a RTI DOSEGUARE 100 and a FJ 2020).

3 CT scanner were selected in this study. The QC tests were made with VICTOREEN CT performance phantoms. The doses were measured with pencil ionization chamber and standard head/body phantoms. The dose profile and CTDI in free air were measured using a set of 36 LiF chips inside a specific holder.

The results of QC tests for 16 fluoroscopic and 3 CT units reveal that most performance parameters are satisfactory.

The DAP values varied from 8 to 48 Gycm^2 with an average value of 21 Gycm^2. According to chest examination procedure used and CT characteristics, weighted $CTDI_w$, Dose-Length product (DLP) and effective dose (E) for 15 patients were estimated. The average values of them were 29mGy, 612mGycm and 10 mSv respectively.

The conclusion from this study was drawen that possible to choose dose reference level can be valid worldwide for all X-ray examinations.

Introduction

A co-ordinated research programme (CRP) in 9 countries of Asia and Far East with IAEA, entitled "Radiation Dose in Diagnostic Radiology and Methods for Dose Reduction", has been launched since 1994. The aim of the project was to explore the potential for dose reduction for some types of X-ray examination, [1] to assess whether available dose reference values could be applied in Asia region. [2] The programme of four years has been instituted in two phases. The first phase of the CRP dealed with conventional radiographic units and the second phase with fluoroscopy and computed tomography. This paper reports work on second phase of the CRP.

Materials and Methods

The fluoroscopic systems selected in the programme included: 3 mobile C-arm systems, 12 remote control tables, and 1 system without image intensifier. The total 16 units were selected from 4 hospitals.

The service lives of CT scanners selected in the programme are: 2 years for 1 CT , 4 years for 1CT and 5 years for 1 CT.

The 2nd round of intercomparison and calibration of TLD systems was finished in January 1998. 50 chips of China-made LiF-TLD were sent to National Radiation Laboratory(NRL) in New Zealand which was responsible for the TLD intercomparison and calibration.[3]

The quality control(QC) tests for fluoroscopic units were made with RMI QC kit. The dose and dose rate for the fluoroscopic units were measured with the PTW DIADOS and TRI Solidose 400 dosimeters.

Five patients per hospital(room) were selected for barium meal(upper GI) fluoroscopic examinations and the dose was measured using a calibrated DAP meter consisting of made Sweden RTI DOSEGUARD 100, or China made FJ2020.

The QC tests for CT scanners were made with VICTOREEN 76-410-4130 and 76-421 phantoms. The dose for CT scanner was measured with VICTOREEN Model 660, 660-6 CT probes and the head/body dose phantoms.

In order to use the Monte Carlo data to calculate effective dose to patients for a CT examination,

it is necessary to know the absorbed dose free-in-air on the axis of rotation of the CT scanner.[2] This can be determined using a set of 36 LiF-TLD chips stacked together inside a specific holder which can be aligned along the axis of rotation of the CT scanner using simple support jig. The TLD were calibrated in air kerma with calibration factor from NRL, New Zealand.

The dose descriptor relating to a single CT slice is expressed as the CTDI. A weighted CTDI(CTDIw) and the Dose –Length Product(DLP) in the head or body CT dosimetry phantoms were derived from the measured $CTDI_{air\ 10}$. [2] The organ doses and effective dose(E) to patients in the study may be derived from kVp, mAs, slice thickness, number of slices, couch increment, start and finish positions and the CTDI/mAs measured free-in-air on axis for the CT scanner, using CTDOSE programme supplied by New Zealand and NRPB250 data base by UK. The patient weight of 5510kg was selected for the chest CT examination.

Results and Discussion

From results of TLD calibration a precision of 5% or better at 0.1 mGy could be achieved. This fact makes the system attractive for low dose measurements in diagnostic radiology with satisfactory accuracy and precision.

The results of QC tests for 16 fluoroscopic units are summarized in Tablehe and for 3 CT scanners in Tablean. A large majority of the units is satisfactory.

Tablebl. Quality control of CT units; summary of QC results for a 10 mm slice thickness.*

Hospital/Room	E/1	F/1	G/1
kV	120	125	130
mAs	320	455	210
Scan time (s)	4	7	3
FOVOVcmm_	25	24	24
Matrix	51212512	51212512	51212512
Algorithm(soft tissue)	standard	Standard	standard
High contrast resolution	1.0	1.0	1.0
CT number calibration:			
air	-976.0971.0	-999992.2	-1000.7102.5
polye	-71.8713.1	-101104.8	-81.3813.0
polys	-35.2353.4	-51513.3	-23.6232.8
water	1.1.13.0	-28284.6	1.6.63.0
nylon	85.95.3.5	744_4.1	100.5003.9
polyc	93.33.3.1	911_6.1	104.0043.2
acrylic	116.0163.6	955_2.7	127.1273.2
CT# contrast scale CS = 1/S CTairTaCTwaterTw	-1/977	-1/971	-1/1002
Low contrast delectability (mm)	3.0	3.0	3.0
Noise: SD of water SD*100*CS(%)	0.30	0.44	0.42
Uniformity(min-max)	3.0	5.0	2.0
nCTDI10cm0cairirmGy/mAsGy	0.334	0.215	0.302

* Standard head techniques for the CT units.

Table b summarizes all mean values of the radiological factors and the DAP for barium meal examination.

Assessing dose to patients from fluoroscopic examinations was always difficult, mainly due to the dynamic nature of the investigation: many parameters (kVp, mA, field position and size) were variable during the same examination and others (number of exposures, fluoroscopy time) from patient to patient. From Tables kV it can be seen that the range of mean DAP values (13.6 - 27.9 $Gycm^2$) as encountered in clinical practice at 4 fluoroscopic units for the upper GI studies is relatively small, especially when it is taken into account that large variation existed in numerous aspects of each

examination, all were closely related to patient dose. This involves, for example, the variations in the fluoroscopy time(0.57 – 8.7 minutes), in the dose rate at the entrance surface of image intensifier(9.0 – 108tiGy/min), in the entrance dose at the surface of phantom(3.9 – 23.5mGy/min) and in number of exposures(3 – 12 images).The highest Dose-Area Product was measured at fluoroscopic unit A/1 which can be explained by the combination of high required entrance dose at the surface of the image intensifier during fluoroscopy and radiography, long fluoroscopy time and great number of exposures.

Table ab. Patient dose measurement; barium meal(upper GI, not follow through) examination *

Parameters	A/1	B/2	C/1	D/1
(tolerances indicated with) Patient data:				
- Average age(yearsd)	526	514	3919	4019
- Average weight(kgsd)	57.29.8	59.85.2	636.7	59.48.4
Mean number of images(nsd)	92.9	9.21.6	5.22.4	60
Mean fluoroscopy time (minutessd)	4.83.0	6.12.3	6.12.6	4.41.2
Dose Area Product(Gy.cm^{2}sd)	27.914.3	13.62.5	18.89.7	22.06.8
	(27.9-47.89)**	(9.84-15.38)**	(10.37-35.50)**	(15.49-31.24)**

* The data for 5 patients per room has been recorded and the patient weight 60 10kg has been selected.
** Range in parentheses

The results of patient dose evaluation in CT chest examination are summarized in Table e. The table shows the average weighted CTDI for a single slice in the patient chest examination, the Dose-Length Product for the complete examination and the average effective dose. These average dose values in hospitals E/1 and G/1 compare rather well with the CEC reference dose values for the chest CT examination, the average in hospital G/1 is higher than the reference value.

Table ab. patient dose evaluation in CT; chest, general examination *

Hospital Room	E/1	F/1	G/1
Average age	666_5.3	555_4.6	588_6.0
Average weight (kg)	577_2.7	600_1.5	555_3.5
Technical parameters:			
Average kV	120	130	125
Average mAs vevve	300	455	150
Scan time(s)	3.0	7	3.0
Slice thickness(mm) cecce	10	10	10
Average no. of slices vevve	222_4	200_3	222_2
Average couch increment (mm)	10	10	10
Examination performed: without(N), with(Y) or without and with contrast media(NY)	None	None	None
Dose evaluation:			
Average CTDIw = nCTDIw.C (mGy)	27.1	43.0	17.2
Average DLP = nCTDIw.C.T.N(mGy.cm)	596.2	860.0	378.4
Average Effective Dose (mSv)	9.8	10.4	8.2

* The data for 5 patients per room has been recorded and the patient weight 5510kg has been selected.

Conclusions

Quality assurance programme for X-ray diagnosis were begun in China in the mid 1980s and became firmly established in early 1990s, when the national regulations and standards were made. This kind of CRP is considered a good and cost effective start for national projects on radiation

protection and quality assurance in diagnostic radiology in developing countries.

It was noted in the studies that the traditional fluoroscopy (without II), upper GI with barium meal for fluoroscopy, and the CT examinations often caused higher absorbed doses to patients than these of conventional radiography.[4] It seems possible to choose reference levels of dose indicator that are valid worldwide for all X-ray examinations, including radiography, fluoroscopy and CT scanning.[5]

Acknowledgement

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References

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Tableab. Quality control measurements on fluoroscopic units

arameters olerances indicated with *)	A/1	A/2	A/3	A/4	A/5	A/6	A/7	B/1	B/2	B/3	B/4	B/5	C/1	C/2	C/3*	D/1
V AccuracyV 100_0_*	NM	A	NM	NM	A	A	A	A	A	NM	A	A	A	A	NA	A
VL, mm of Al,(measure at 80 kVVL	NM	NM	NM	NM	NM	A	A	A	NM	NM	NM	A	A	A	NM	A
imer Accuracy (10%)*	NM	NM	NM	NM	NM	A	A	NM	NM	NM	NM	NM	NM	NM	NM	A
As linearityAs100_0_*	NM	NM	NM	NM	NM	A	A	A	NM	NM	NM	NM	A	A	NM	A
utpututmGy/mAsGy at 80 kV, at 50 cm	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
ght/Radiation Beam Alignment (deviation at n)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
igh contrast resolution (field size of 23 cm nearest,																
rmal mode of fluoro):	1.2	1.4	0.6	1.6	1.2	1.0	0.6	0.8	1.4	2.4	1.2	0.6	1.2	2.4	0.9	1.2
the centre (lp/mm)	1.0	1.2	0.6	1.6	1.2	0.8	0.6	0.8	1.4	2.4	1.2	0.6	1.2	2.4	0.9	1.2
the peripheral(lp/mm)																
ose rat at the entrance of I.I																
eld size of 23 cm of nearest, normal mode fluoro):	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	None	Y
idriY/N/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	None	Y
BCBCY/N/N	85 1.7	79 2.0	85 1.4	76 6.3	88 1.4	76 1.6	78 0.2	76 1.3	75 2.1	71 3.2	80 1.5	85 0.5	70 1.0	88 2.1	-	88 2.0
V_mA	108	40	20	27	44	58	9.0	33	68	36	72	33	21.4	67.8	-	44.9
ose rateososGy/miny/																
trance dose rate to the patient																
eld size of 23 cm or nearest, normal mode																
oro grid in):	90 1.7	77 2.0	79 1.4	73 6.8	89 1.4	77 1.6	70 2.0	76 1.2	78 1.6	70 3.0	83 1.7	80 1.0	74 1.1	89 2.1	70 2.0	74 1.3
V_mA	16.1	23.5	7.9	5.7	10.7	11.4	6.83	6.5	9.9	11.5	12.0	3.9	5.5	13.9	46.8	5.6
se (mGy/min)																
ximum entrance dose rate to the patient																
ghest image quality,																
ost mode):																
west field sizeowcmm_	23	23	23	13	23	23	23	23	23	17	23	23	23	15	-	23
V_mA	124 2.4	112 4.0	95 1.4	125 16	121 2.6	124 2.4	100 4.0	120 3.0	114 2.4	111 6.0	115 2.3	120 1.0	120 1.9	125 4.0	-	123 2.5
se rate at 30 cmosmGy/minGy	36.9	99.1	11.4	60.8	33.34	40.0	26.7	41.2	29.4	58.6	27.9	8.2	24.0	55.7	-	29.4

NM = Not Measured A= Acceptable * without image intensifier

RADIATION DOSE IN RADIOGRAPHY AND METHODS FOR DOSE REDUCTION

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Abstract

The research contract between the International Atomic Energy Agency (IAEA) and laboratory of Industrial Hygiene(LIH), China, was conducted from 1994 to 1998 and entitled "Radiation Dose in Diagnostic Radiology and Methods for Dose Reduction", involving some of Asia and Far East countries. The results of the research have demonstrated significant dose reduction has been achieved without any loss of diagnostic information. The CEC diagnostic reference dose values can be valid for conventional radiography examinations in China.

Introduction

A Coordinated research programme of IAEA in cooperation with 9 countries in Asia and the Far East has been launched since 1994.[1]

The programme of four years was instituted in two phases. Phases 1 of the CRP dealed with conventional radiographic units and phases 2 with fluoroscopy and computed tomography units. The report is the results obtained in the phase 1.

The scope of the phase was the participant to be asked to assess the radiation dose reduction due to implementation of QC procedures in the sample of hospitals. This assessment was involved: classification by type and frequency of X-ray examinations; Analysis of film-reject rate; Measurement of patient dose in radiography pre and post-QC implementation of each selected examination; QC measurements of X-ray performance; Dissemination of Information and training of the hospitals and image quality evaluation of using image quality criteria in the CEC working document.[2]

Materials and Methods

Four hospitals were selected as the co-ordinator on implementing the project. In each hospital two X-ray conventional radiography rooms were chosen to collect information of eight X-ray projections which should estimate the frequency of examinations and the film reject rate during a period of two weeks for pre- and post –QC implementation.

In order to obtain entrance surface dose (ESD) values for each projection performed in each hospital, measurements should be carried out on a sample of 10 adult normal sized patients (65Kg5) using sets of 4 chips of LiF TLD to the patient's skin in the center of the beam for pre- and post-QC implementation. The organ dose and effective dose were calculated using software programmes provided by IAEA from NRPB in English and NRL in New Zealand. The TLD systems were sent to the NRL to perform calibration and intercomparison exercise.

QC tests for each X-ray unit were made with RMI QC kit (U.S.A) according to the technical prerequisites of the CRP. Once the QC tests are finished, the results were analyzed in order to identify possible improvement and to implement corrective actions with the relevant parameters which may influence the ESD.

Results

Table I presents the results of measured ESD by projection type and by hospital.

Table I . The results of measured ESD mmean me1SD, mGy1S

Hospital	Projection Types					
	Chest	Skull		Lumber Spine		Pelvis
	PA	PA	LAT	AP	LAT	AP
pre-QC						
A	0.270.0.04	3.813.0.66	3.533.0.87	12.36121.30*	14.883.30*	11.702.60*
B	0.450.0.13	3.233.0.57	2.242.0.40	8.242.20	19.062.54	5.071.26
C	0.280.0.05	5.055.1.47	4.024.0.91	7.001.00	15.701.80	2.601.20
D	0.380.0.06	***	***	6.541.40	13.502.90	7.160.87
post-QC						
A	0.290.05	5.881.09	4.840.77	8.390.68	8.030.62	1.740.49
B	0.330.03	3.701.00	2.970.64	5.350.94	15.21.39	4.600.70
C**	0.090.02	4.702.10	***	3.901.40	8.401.20	1.200.30
D	0.240.05	***	***	7.782.07	16.265.43	6.421.94

*: Tube potential is incorrect. **: Adopted high speed class of screen film combination.
***: Patient number is less than 10.

Table II shown the results of calculated effective doses E(ICRP 60) .

Table II . The results of E (mean .1SD,mSv)

Hospital	Projection Types					
	Chest	Skull		Lumber Spine		Pelvis
	PA	PA	LAT	AP	LAT	AP
preprQC						
A	0.040.0.008	0.020.0.06	0.030.0.005	1.131.0.14	0.240.0.06	1.671.0.42
B	0.070.0.02	0.030.0.01	0.020.0.01	0.760.0.21	0.300.0.04	0.690.0.17
C	0.060.0.04	0.040.0.01	0.030.0.01	0.760.0.14	0.290.0.04	0.390.0.19
D	0.060.0.01	*	*	0.670.0.17	0.240.0.06	1.071.0.16
postpoQC						
A	0.050.0.01	0.040.007	0.030.006	0.930.09	0.160.01	0.270.09
B	0.050.0.003	0.030.01	0.020.006	0.480.09	0.220.03	0.620.12
C	0.010.004	0.030.02	*	0.410.15	0.140.02	0.190.05
D	0.040.01	*	*	0.820.24	0.290.11	1.110.52

*: Patient number is less than 10.

Table III shows the percentage of average dose reduction where different kinds of technical actions were adopted.

Table III. Results of Different dose reduction actions.

Dose Reduction Action	Hospital/ Room	Projection	Average Dose Reduction(%)
Increased Tuble Potential	A/2	Lumber Spine (AP)	32
	A/2	Lumber Spine (LAT)	45
Increased Screen Film Sensitivity	C/1	Chest (PA)	67
	C/2	Lumber Spine (AP)	44
	C/2	Lumber Spine (LAT)	46
	C/2	Pelvis (AP)	54
Increased Filtration	B/1	Chest (PA)	27
Increased Tube Potential & Increased Screen Film Sensitivity	A/2	Pelvis (AP)	85

Table IV presents the examination frequencies of each hospital during 2 weeks for pre-and post-QC implementation.

Table IV. Examination frequencies by hospital (%)

Hospital	Total Patients Number	Projection Types						
		Chest		Skull		Lumber Spine		Pelvis
		PA	LAT	PA	LAT	AP	LAT	AP
Pre-QC								
A	908	37.7	10.6	0.7	0.8	24.9	23.7	3.0
B	1269	55.7	17.3	2.1	2.0	10.3	9.9	2.7
C	1091	53.8	10.4	0.01	0.01	17.4	16.0	2.4
D	766	41.8	11.0	0.0	0.0	23.0	21.4	2.8
post-QC								
A	929	37.2	12.9	0.01	0.01	27.1	22.8	0.02
C	522	35.6	14.8	0.02	0.02	27.8	21.8	0.02

Table V presents the film reject rate of each hospital during 2 weeks for pre-and post-QC implementation.

Table V. Film reject rate by hospital and by case

Hospital	Films No.	Rejected Films No.	Rejected Rate(%)	Cases			
				Too Dark	Too Light	Position	Others
Pre-QC							
A	908	34	3.7	12	18	1	3
B	1269	72	5.6	28	36	3	5
C	1091	39	3.6	14	15	3	7
D	766	25	3.3	11	9	2	3
Post-QC							
A	929	12	1.3	5	6	1	0
C	522	4	0.8	3	0	1	0

Conclusions

1. The High chest (PA) frequency projection is 50% and the Low skull frequency projections (AP and LAT) are less than 1% because of the use of CT scanner.
2. The film reject rate varied from 3.3% to 5.6% in these four hospitals pre-QC due to the inappropriate set of the parameters. After the corrective actions for post-QC the reject rate reduced to less than 1.3%.
3. Most of the measured ESD for the projections is lower than the CEC reference values.
4. Four kinds of dose reduction methods used in different X-ray rooms, the dose reduction varied from 27% to 85%.

Acknowledgement

This work was supported in part by the IAEA under contract number 8221/R1, We would like to thank Ms. Modupe. Oresegun and Mr. P. Ortiz-lopez for their assistance.

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MEDICAL AND BIOLOGICAL APPLICATION OF RADIOPHARMACEUTICALS IN BANGLADESH

Atia H.Jehan

Abstract

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

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Nuclear Medicine is globally practiced as a safe, non-invasive and effective mode in the diagnosis and treatment of human diseases. Radionuclide imaging is based in the detection of spatial and temporal distribution of an administered radiopharmaceutical into the body. A Radiopharmaceutical is a compound of a radionuclide and an organ specific pharmaceutical.

In Bangladesh only generator produced isotopes are available as there is no cyclotron and of these 95% are used for diagnostic purposes , while 5% for therapeutic treatment.. Radiolabelling procedures are carried out in the hot labs of the individual centers. The common isotopes,radiopharmaceuticals and their applications in Bangladesh are shown in Table 1 .

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

Table 1 : Diagnostic Application of Radiopharmaceuticals

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

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

Table : 2 Therapeutic Application of Radiopharmaceuticals

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

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

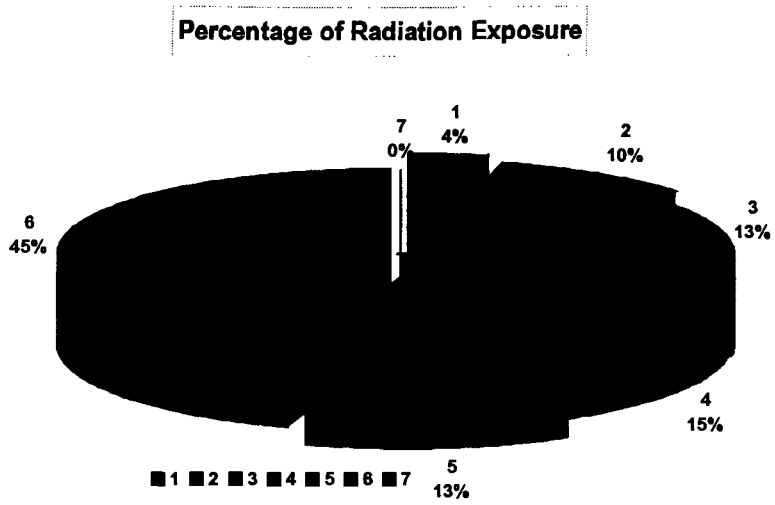

Figure 1Percentage of Radiation Exposure

1-Nuclear Medicine; 2-Diagnostic X-rays; 3- Internal (Inside Human Body); 4-Terresterial Radiation (Rocks & Soil); 5- Cosmic Rays ; 6- Radon ; 7-Others(<1%)

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

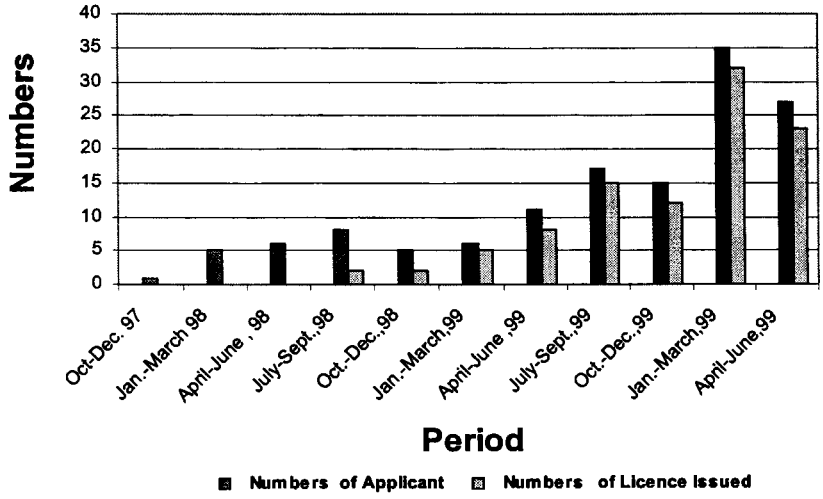

Figure 2 Status of Licence Applications received and Issued

Misuse and uncontrolled sources may cause burn injury while long term or stochastic detriments may cause cellular mutations or genetic disorder. There is no threshold on the amount of exposure required for causing these disorders in the human body. Wearing gloves and film badge monitoring , act as a filter against radiation hazard.
An IAEA sponsored workshop on **Radiation Protection and Quality Assurance** was held recently in the capital with participants from nuclear medicine , radiology and radiotherapy department. Radiation protection and the importance of quality assurance were highlighted in the workshop.

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

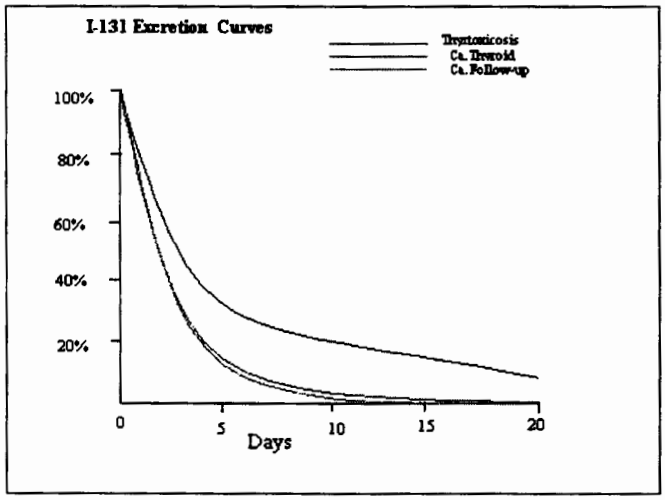

Figure 3 I-131 excretions curves in percentages of administered activities

spite of all precautions these patients fail to realize the importance and ignore all the advise given to them. Indiscriminate disposal of excreta and saliva cause environmental pollution. The rate of Iodine excretion is shown in fig.3.

CONCLUSION

The risk of radiation exposure associated with nuclear medicine practice is comparatively is lower than that of radiotherapy and radiological investigations. The possibility of contamination and isotope spill is high but limited within the dispensing room and laboratories. The radiation hazard to the general public and the environment

must not outweigh the benefit to the patient. The practice demand attention of the facility management and regulators. The quality of radioisotope , quantity , supply and storage plays an important role in prevention of radiation hazard to the occupational workers and patients. Using standardized equipment, trained personnel and proper radiopharmaceuticals, nuclear medicine practice may be considered as one of the safest non invasive and accurate method in the diagnosis and treatment of medical disorder.

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ok Mamo

IAEA-CN-85/144

STUDY ABOUT DIAGNOSTIC QUALITY IN A PUBLIC-CENTER OF MAMMOGRAPHY OF SANTA FE – ARGENTINA

Abstract

The objective is to apply a method that allows us to evaluate the diagnostic quality of a public-center of mammography and to validate it.

The representative centers of a social class were grouped; this one is evaluated measuring the mechanics, electrics, dosimetrics and personal parameters of the process to get the mammography diagnostic. The original study and the respective report, was submitted to the valuation of a panel of experts, who evaluated image, technique and diagnostic. The equipment and techniques used are described in this case.

The judgment of the ACR and the Argentine legislation are applied. The dosimetric results of the mammography practice, serve to determine the local reference levels. The whole people who has intervened in the diagnosis is evaluated, and the services that can influence it. Seeking the parametric sensibility in relationship with the succeeded and precocious diagnosis, the success of it is confirmed by the panel of experts.

We concluded indicating that the success percentage in the diagnosis is about 98,36%, that there is 100% of coincidence among the perception and the value of the study quality. The valuation of the image reaches 69,2% of the maximum score, and the placement technique, 73,9%. The parametric sensibilities of the principal variables are discussed.

ESTUDIO SOBRE CALIDAD DIAGNOSTICA EN UN CENTRO PUBLICO DE MAMOGRAFIA DE SANTA FE - ARGENTINA.

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OBJETIVO

El objetivo es evaluar la calidad que tiene el centro para emitir un diagnostico precoz y certero sobre mastología y relacionarlo con los diferentes parámetros que intervienen en el proceso de obtención de dicho diagnostico.-

METODO Y EQUIPOS :

Se seleccionó un centro al azar que representara al acceso que tienen un determinada clase social y se evaluaron cada uno de los parámetros cuya nomina se puede apreciar en la tabla de resultados que se informa como N° 1.

Con la aceptación de las pacientes, el centro y el médico que diagnosticó originalmente los estudios, se realizó la copia del diagnostico y de las placas y se hacen todos anónimos para someterlos a la evaluación de un panel de expertos, reconocidos por la sociedad profesional, que evalúa la calidad de la imagen (Blanda / Normal / Quemada – Sobrexpuesta / Normal / Subexpuesta); la técnica utilizada para el posicionamiento y proceso de obtención de la imagen (Identificación – Artefactos – Sucia - Mal comprimida – Movida - Vista del músculo pectoral – Pliegues - Nariz de camello - Pezón incluido – Axila – imagen cortada); el Diagnóstico (Coincidencia total / parcial / no hay

coincidencia – informe inespecífico – sugerencias explicitadas correctas / incorrecta) y por último se considera la evaluación general de la placa con su capacidad para emitir el diagnostico y si ha lugar, se explicite un comentario general de la mismas.

Para la evaluación de los parámetros mecánicos, eléctricos y dosimétricos del centro se aplicaron los criterios de la ACR (1) y de la legislación Argentina (2) además de las recomendaciones que se explicitan en el material no impreso (3) y la tesina (4)

Los equipos y herramientas utilizadas fueron: Densitómetro Digital Tobias Associates Modelo TBX, Sensitómetro Nuclear Ass. , Precision Photometer Nuclear Ass. , Thermometer Digital RMI, HVL of Al and Cu , Mamographic Resolution Estándar , Star X-Ray Test Patterns 0,50° y 1° , Slit Cameras, Mamographic Step Wedge 18-239 Nuclear Ass., Control Tools Screen Film, duplicator AGFA, mAmeter UNFOR y Dosimeter PTW DI4/DL4 con camera PTW Modelo 3223, para baja energía.

RESULTADOS:

El equipo evaluado es un GE Senographic 600T- Senix HF, la maquina reveladora automática es AGFA y se usa compartida con el servicio de Radiología general, las pantallas reforzadoras y las películas usadas son KODAK. La carga de trabajo es de 200 estudios por mes.

Los parámetros evaluados y su resultados se explicitan en la tabla N° 1

Tamaño de la mancha focal	Nominal: 0,3 Medido:ش 0,34 - 0,39	Tol = 0,45	Pass
kVp – Reproducibilidad	R = 0	Tol = 2%	Pass
kVp – Precisión	P = 1,9%	Tol = 4%	Pass
Tiempo de exposición	A 24 kVp , R = 0,7	Tol = 10%	Pass
HVL	A 24 kVp , <0,3 mm de Al		Pass
Rendimiento	a 24 kVp ,9,8 mR/mAs	Tol = 8	Pass
Distancia foco imagen	Nominal 65cm Medido 63 cm Δ1,8%	Tol = 2%	Pass
Fuga	< de 1mGy a 1 m		Pass
Campo de luz / de radiación	1,5 mm en la peor condición	< ± 5	Pass
Dosis Kerma en aire	18,7 mGy		
Dosis Glandular Media	3,12 mGy	Tol=4mGy	Pass
Revelado Temp.. y tiempo	Revel 34,8°C/Fija 34,1°C Total 210s		
Sensitometria	v+b=0,19 IV=1,2 paso 15 IC=2,69-0,54=2,15 P 17- P 14		
Cuarto oscuro	Hermeticidad = Buena, Luz de seg.= no usa, Frecuencia de limpieza y cambio = 15 días		
Negatoscopio, luminancia	Centro 2012 nit		Fail
Negatoscopio, homogenidad	31%		Fail
Lectura Iluminación ambient	25 lux	< 50 lux	Pass

El médico informante es uno (1)(por lo que no se realizan la doble lectura del film) y su especialidad es en mastología, no es radiólogo tiene entre 15 a 20 años de experiencia y ha asistido a 37 cursos, conferencias, talleres y congresos en los últimos 5 años.

Las técnicas de mamografía son dos ambas con titulo terciario, especialización no estructurada en mamografía y con asistencia a conferencias y congresos en los últimos 5 años.

El centro tiene servicio de mantenimiento interno de malas condiciones de prestación, no tiene servicio de física médica y el oficial de protección radiológica es el medico con reciente autorización individual para el manejo de equipos Rayos-X.

Para la evaluación de la calidad diagnóstica de la placa se usó dos grupos diferentes de evaluadores, arrojando el resultado que se muestra en la tabla N° 2

Nº	IMAGEN					TECNICA					DIAG.					EV. GRAL					TOTAL	OBSERVACIONES
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5		
1			X					X						X				X			13	Sucio,Rayas,Falta pectoral,Falla revelado
2			X					X						X				X			13	Sucio,Rayas,Pezón incluido
3		X						X						X					X		13	Sucio,Rayas
4			X					X						X				X			13	Sucio,Rayas,Pliegues, Pezón incluido,Artef Cal
5			X						X				X					X			13	Sucio,Rayas,Imagen cortada,Blanda, Artef Cal
6			X							X				X					X		16	Sucio,Rayas,Quemada
7			X					X					X					X			12	Sucio,Rayas,Pezón incluido,Falta desc Cal vasc
8			X					X							X			X			14	Sucio,Rayas, Falta pectoral, Artef Cal
9		X						X					X					X			11	Sucio,Rayas,Falta pectoral, Artef,Diag Bien/Mal descri
10				X					X						X				X		17	Sucio,Rayas,Pezón incluido,Pliegues, Artef Cal
11			X					X						X				X			13	Sucio,Rayas,Pezón incluido,Pliegues
12			X					X							X			X			14	Sucio,Rayas,Blanda,Imagen cortada
13		X						X							X				X		14	Sucio,Rayas,Blanda, Falta compresión
14			X					X						X				X			13	Sucio,Rayas,
15				X					X						X				X		17	Sucio
16		X							X						X			X			14	Sucio,Pliegues,Pezón incluido
17		X								X				X				X			14	Sucio,Rayas, Artef,Imagen cortada
18				X					X					X					X		16	Sucio,Blanda,Pezón inclui, Artfac,Falta descr Cal benig
19			X					X						X				X			13	Sucio,Pezón incluido,Artef
20			X				X								X			X			13	Sucio,Pezón incluido,Artef
21		X							X						X			X			14	Sucio,Rayas,Artef
22		X					X								X			X			12	Sucio,Rayas,Pezón incluido,Artef
23				X					X						X				X		17	Pezón incluido
24			X					X				X						X			11	Sucio, Imagen cortada, Diagnós observado
25			X					X				X					X				10	Sucio,Pezón incluido,Artef, [redacted]

En el 92% de las placas, la calidad diagnóstica fue evaluada como Regular o Buena, (58% Regular y 42% Buena), solo dos estudios resultaron con una valoración por debajo de regular. La evaluación total fue el 82,4% del valor máximo.

El diagnóstico fue coincidente en 24/25 de los casos, solo se observó en 1 caso que faltaba la descripción de microcalcificaciones agrupadas, en 1 faltaba describir microcalcificaciones vasculares, en 1 falta descripción de microcalcificaciones benignas y 2 se observaron por informe escueto.

La imagen fue calificada con un promedio de 2,88/5, porque el 96% de las placas se encontró que estaban sucias, en el 68% rayadas, en el 48% con artefactos que simulaban microcalcificaciones y/o masa y 16% estaban blandas o quemadas. Se llegó a la conclusión que existen severos inconvenientes antes y durante el procesado de la película.

La técnica se evaluó en promedio con 3,28/5, por el posicionamiento y la compresión de la mama, (se encontró que en el 50% de los estudios tenían alguna placa con pezón incluido, en el 16% de los estudios alguna placa con pliegues, en alguna placa del 10% no se tomaba el pectoral y solo en el 16% de los estudios alguna placa estaba recortada y en 1 le faltaba compresión.

La evaluación por item de las placas arrojó que la Imagen se valuaba con 2,88/5, La técnica con 3,28/5, el diagnóstico con 4,12/5 y en Percepción general 3,25/5. Arrojando la Evaluación general del Servicio 10,28/15.

CONCLUSIONES:

Los parámetros del equipo dan en todos los casos como cumpliendo con las tolerancias establecidas, excepto los negastoscopios que dan francamente mal.

Se destaca primero la validez del método elegido ya que la Percepción de la calidad del Servicio para emitir un diagnóstico certero (0,66), coincide con la valoración que se desprende de cada uno de sus ítems (0,68).

La otra cosa importante es la relación encontrada entre la evaluación de los expertos y las causas de esa valoración, así mencionamos cuatro:

1°) La falta de un revelador cautivo, la mezcla de marcas, así como el descuido en la limpieza de los chasis, pantallas y películas traen como consecuencia la suciedad, rayas, artefactos, placas blandas y duras, que encontraron los evaluadores y que hacen perder calidad diagnóstica a la placa.

2°) Por otro lado la falta de posibilidad de contar con un chasis de mayor tamaño (24 x 30) y las películas correspondientes (a pesar de contar la máquina con la platina compatible), traen como consecuencia directa las Imágenes cortadas en las placas de mamas grandes y concurren con otras causas que también influencian, a encontrar pliegues, pezón incluido y falta del músculo pectoral.

3°) La alta carga de trabajo, junto con la expertice de las dos técnicas radiólogas y los detalles enunciados en el ítems anterior tienen que ver con la la falta de compresión y problemas de posicionamiento como pezón incluido y pliegues.

4°) Las imágenes sucias y rayadas sumada a los artefactos y a la muy mala calidad de los negatoscopios, agravado por la imposibilidad de doble lectura, son la consecuencia de los inconvenientes detectados en el diagnóstico.

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IAEA-CN-85 - 145

Reject
a pity

THE RADIATION PROTECTION ASPECTS IN GENERAL RADIODIAGNOSTIC

About 13 611 cases occured in 1998 in
BONDEKO clinic D.R.C. Kinshasa ?

By

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1. SUMMARY

The assessment of the collective dose absorbed within a medical formation, is a difficult exercise. This difficulty worsens more again in a situation of crisis where the acquirement of quantification dosimetric materials curls the commits suicide. ?

In spite of these asperities, we imagined to measure the dose as well as effects there pertaining through the transmitted irradiation and received on X-Ray films of different radiological explorations during one year.

These explorations left in two strata: the special exams (to accumulated strong irradiation) and the standard exams (to reduced irradiation). The big number of the plain exams added to a reduced population of special exams led us to 13.611 various measurements clichés.

It is these clichés that have been considered as dosifilms having received a X irradiation that it was necessary to quantify; then, this irradiation has been extrapolated to search for the hypothetical detriment caused by this X. radiances.

The comparison with the descended data of other countries having long radiological tradition cleared a difference statistically meaningful testifying the precariousness of our detection means there and imploring a revision of radiotechnical situation on the human plan as well as on the one of infrastructures : radiological devices and dosimeters

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2. MATERIAL AND METHOD

As stipulated previously, we are served for this survey, a population radiographical production of our radiology service: BONDEKO Clinic. By a mechanism of pull to the fate we fell on the year-radiographical – year 1998. Hence all the production going from January to December had to serve us as material exploration.

The stratification of the clichés permitted to have after exhaustive numbering:

+ 4630 clichés all disconcerted measurements (special exams)

+ 8981 clichés all disconcerted measurements (standard exams)

13.611.

This production corresponded to:

- 6.643 patients for the stadard explorations
- 592 patients for the special explorations.

We left from a principle radiodosimétrique that wants that clichés are considered as the surface of welcome of a dose delivered to the sick.

However, " all things being otherwise equal'', without the fact that the other interactions can brake and decrease the transmission of the –X-Rays, we suppose that the quantity of Rx having provoked the shade, (first latent then visible), of the human body, is the one that had been transmitted by X-Rays Tube.

The radiant energy, coming from the XS particles is the one, which through the flux and the fluence of particles (energizing, spéctrique) provoked this picture.

If now, we calculate the delivered dose (Rin) we can assume that the irradiation of the cliché is it (R output) received dose. The difference between Rin-Rout + ΣQ will be the quantity of radiuses received by the sick, having crossed and acts biologically on the sick and in its organs (= Rin - Rout + ΣQ expressed in GRAY or in Sievert.

One will calculate so the surface radiated of the cliché at 3/4 (1/4 being zones outside of the picture) complete surface of exhibition; one will have to look for the J/kg.

3. RESULTS

Calculations schematized in materials and methods permitted to have:

1. An average of 2 clichés used by patient at the time of the standard exams and 8 clichés for the special exams.

2. According to values recommended by the A.I.E.A. [1] the collective efficient dose would be:

The special exams would give a HIMSELF = 47,4 Sieverts

The standard exams would only make THEMSELVES = 89,6 Sieverts.

These results would drive to an exhibition of 10,86 mSvs for the special exams and 9,98 mSvs for the standard exams.

Thus, the difference would be 0,884 mSvs between the two explorations.

3.Risks incurred with these rates of exhibition, according to the international sources would be of

TABLE I : RISKS INCURED BY X-Rays

Examen/Risque	Cancer	Heredity	Detriment
Special	2,4	0,5	3,4
Standard	4,5	1,4	6,5

4. During all these explorations the delivered energy and received by the sick would be therefore 0,025 calories/Cm2 for the standard exams and 0,034 calories for the special explorations a difference of 0,009 calories in special exploration favor.

[1] Cours Post universitaire de Radio protection,Volume2,1995, P. 291-292 et 324-325

4. CONCLUSION

The term of our communication was to especially demonstrate the precariousness of our protective means when it is about a special exam in conventional radiology. We have just shown that the sick would be minus 6,15 times exposed in standard exploration that he would not be in specialized exploration. Indeed, that the collective efficient dose of patients radiated is raised more in specialized explorations of 80 mSvs (patient in only one exam and 13,5 mSvs only in exploration standard lasting a sitting) would make only confirm this unhappy truth. It means that every drawn cliché during a special exploration delivers 10,86 mSvs; the one drawn in standard exam would represent 9,98 mSvs .

Risks incurred that would explain themselves by the caloric loads more important of an exploration in relation to an another one is only illustrative. It was about quantifying risks of 592 patient examined especially against 6.643 received for a standard diagnosis to the X-Rays Service, an enormous difference gradient: 11,22!

We call some to the International Processes to make reach us the more effective radiological techniques and less irradianteses, to provide to seminaries of retraining of our agents in radiology mainly on all concerning radiation protection field , to pursue researches to find some less costly detectors for countries of the Third-world , easy-for-use.

? General? Right?

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MEDICAL RADIATION PHYSICS TRAINING EMERALD

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ABSTRACT

Training of young medical physicists is an essential part of the framework of measures for Radiological Protection of Patients. The paper describes the Medical Radiation Physics Training Scheme EMERALD, developed by an European Project Consortium. EMERALD Training covers the Physics of X-ray Diagnostic Radiology, Nuclear Medicine and Radiotherapy. Each of these 3 modules covers 4 months training period. The EMERALD training materials are 3 Workbooks with tasks and a Teachers' Guide (total volume approx 700 pages) and 3 CD-ROMs with image database.

Introduction

The increased awareness that medicine delivers about 95% of people's exposure to radiation from man-made sources led to number of measures being taken within the European Community. Subsequent Policy Statements of the European Federation of Organizations for Medical Physics (EFOMP) - the regional chapter of the International Organisation for Medical Physics (IOMP) - specified further measures for radiation protection and requirements for the knowledge and skills of the professionals responsible for the safe and proper use of radiation in medicine. On this basis an EC Leonardo da Vinci pilot project [1] was prepared for developing a Framework of common training modules in Medical Radiation Physics (Physics of X-ray Diagnostic Radiology, Nuclear Medicine, Radiotherapy). These modules are for the training of young graduates and post-graduate students in medical physics or related disciplines, their tutors, as well as other Hospital employees applying radiation to medicine. The partners in the project are a Consortium of Universities and Hospitals from UK, Sweden, Italy and Portugal: King's College London - School of Medicine and Dentistry, University of Lund, University of Florence, King's Healthcare Trust, Lund University Hospital, Florence University Hospital, The Portuguese Oncological Institute, the International Centre for Theoretical Physics in Trieste. The acronym of the project is EMERALD (European Medical Radiation Learning Development). It is Managed and Coordinated by King's College London and is supported by the EFOMP. Special training materials were developed in the framework of EMERALD [2].

General Structure of EMERALD Training Modules

The Consortium developed the three Training modules with a common length of 4 months (80 days) each. During this time the trainee will have to acquire most necessary professional skills. This part of the training was called "condensed" and can be performed in most countries, where training conditions are set up. Further the trainee can spend up to 2 months in his own country/state where he/she can additionally study the local Regulations and professional requirements. The paper here describes the "condensed" training EMERALD.

Each of the three Training Modules incorporates:
- List of Competencies (in accord with the UK IPEM Training scheme);
- Student Workbook with tasks (performance of each task leads to certain competency);
- Structured Timetable (describing the approximate time necessary for each task);

Each task in the Workbooks contains explanations and protocols to be followed and requires answers to specific questions and problems. The proper performance of each task should be verified by the Trainer and on this basis the Trainee can continue with other tasks. To help in this process a Teacher's Guide was prepared.

The main types of tasks are:
- Observing real activities and taking notes
- Using existing Regulations, Protocols, Software
- Using various types of measuring equipment
- Understanding the basic characteristics & parameters of equipment
- Performing Measurements (including Dosimetry), Collecting Results, Calculating Parameters and other activities most often related to Quality Control (QC).
- Full Equipment Assessment (as part of the overall Quality Assurance program)

X-ray Diagnostic Radiology Physics Module

This module was developed mainly by the UK partners. The training tasks in the X-ray Diagnostic Radiology (DR) Physics Workbook are grouped in the following chapters:
- General principles of DR radiation protection;
- General principles of DR quality control;
- X-ray dosimetry and patient dosimetry;
- Radiological image parameters;
- X-ray tube and generator;
- Radiographic equipment;
- X-ray films/screens and laboratory;
- Fluoroscopic equipment;
- Digital imaging and CT equipment;
- Basis of shielding in DR

Nuclear Medicine Physics Module

This module was developed mainly by the Swedish partners. The training tasks in the Nuclear Medicine (NM) Physics Workbook are grouped in the following chapters:
- General principles of Radiation Protection in NM;
- General principles of NM Quality Control organisation and equipment;
- Fundamentals and basic properties of radiopharmaceuticals and radioisotopes;
- Pharmacokinetics and internal dosimetry;
- Single detector systems and survey meters;
- General principles of Scintillation Camera systems;
- Single photon Emmission Tomography – SPECT;
- Positron Emission Tomography with dedicated PET or Dual-Head Coincidence Scintillation Camera;
- Image evaluation and Data analysis;
- Preparation and QC of radiopharmaceuticals;
- QA of equipment and software;
- Radionuclide therapy;
- Radiation Protection of NM staff;
- Radiation Protection of NM patients;

- National and EU legislation in Radiation Protection and Radiopharmacy.

Radiotherapy Physics Module

This module was developed mainly by the Italian and Portuguese partners (with input from Swedish partners). The training tasks in the Radiotherapy Physics (RT) Workbook are grouped in the following chapters:
- Basic methods in Radiotherapy Physics;
- Quality Assurance of a Dosimetric System;
- Calibration of a Kilovoltage x-ray Beam;
- Calibration of a MVXR Beam;
- Calibration of an Electron Beam;
- Calibration of an In-vivo Detector;
- Acquisition of Open Beam Data;
- Acquisition of Dose Distributions and Dose Profiles;
- Acquisition of Wedged Beam Data;
- Manual Monitor Unit and Dose Calculation for Photon and Electron Beams;
- External Beam Treatment Planning using a Computerized System;
- Quality Assurance of an Orthovoltage Unit;
- Quality Assurance of a Teletherapy Unit;
- Quality Assurance of a Linear Accelerator;
- Basic Checks of a Treatment Planning System for external beam therapy;
- Calibration of Brachytherapy Sources;
- Manual Treatment Planning using 192Ir Sources for Interstitial Brachytherapy;
- Manual Treatment Planning for Intracavitary Brachytherapy;
- Surface Moulds in Brachytherapy;
- Computerised Treatment Planning Systems for Brachytherapy;
- Quality Assurance in Brachytherapy.

CD-ROM Image Database EMERALD

Being very expensive contemporary radiological equipment can not be purchased for training purposes. Additionally this equipment is intensively used for diagnostic and treatment purposes. As a result the young medical physicists have extremely limited time for training in the hospitals. The only solution to this problem is to encourage the use of modern educational technology.

In order to provide possibilities for off-site (distance) studying of contemporary radiological equipment the EMERALD Consortium has developed a digital image database (IDB). The volume of the IDB is about 1400 images of Radiological equipment and its components; Block diagrams and performance parameters, graphs, waveforms; QA procedures and measuring equipment; Test objects and image quality examples; Typical images and artefacts, etc. A PC type image browser (ThumbPlus) is used for quick and easy search through the IDB. The browser presents each image as a ~ 128x128 slide, which can be further viewed in its original size (JPEG up to 1024x1024 pixels). Each image is visualised with corresponding caption, on which basis Keyword search of IDB can be performed as well. The IDB is engraved on three CD-ROMs – one for each Training module. The image organisation within each IDB follows the chapters in the Training Workbooks - Fig.1.

Practical Implementation

All teaching materials were tested in practice and refereed. A special European Conference on Medical Physics was organised at ICTP Treiste, on 25-26 September 1998. Senior specialists

from 24 countries gathered tt this Conference to discuss the common European approach to Medical Physics Training using EMERALD. The feedback of this Conference was later used during the editing of all EMERALD Training materials. These materials have now been exported in approximately 35 countries.

For the purposes of dissemination a further projects EMERALD II (EMERALD – Internet Issue) was prepared with enlarged Consortium including the old partners and new partners from France, Ireland, Northern Ireland, Czech Republic and Bulgaria [3]. During this second phase of the EMERALD a sequence of international Seminars "Train-the-Trainer" have been organised in Dublin, Lille, Prague, Lisbon, Lund and London . A special session was held also during the Word Congress in Chicago, WC2000. An interactive Training Multimedia is in development at the moment. This new material will be Internet distributable to assist the distance learning on the subject in the world.

Regular information about the development of EMERALD and the Network of specialists who are using this training can be found at the dedicated Web site: http://www.emerald2.net

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[2] A Training Course for Medical Radiation Physics – EMERALD, related issues: ISBN 1 870722 04 3 ; ISBN 1 870722 05 1; ISBN 1 870722 06 X; ISBN 1 870722 07 8; ISBN 1 870722 03 5; ISBN 1 870722 08 6; ISBN 1 870722 09 4

[3] EC programme Leonardo da Vinci, project EMERALD, ID 80502.

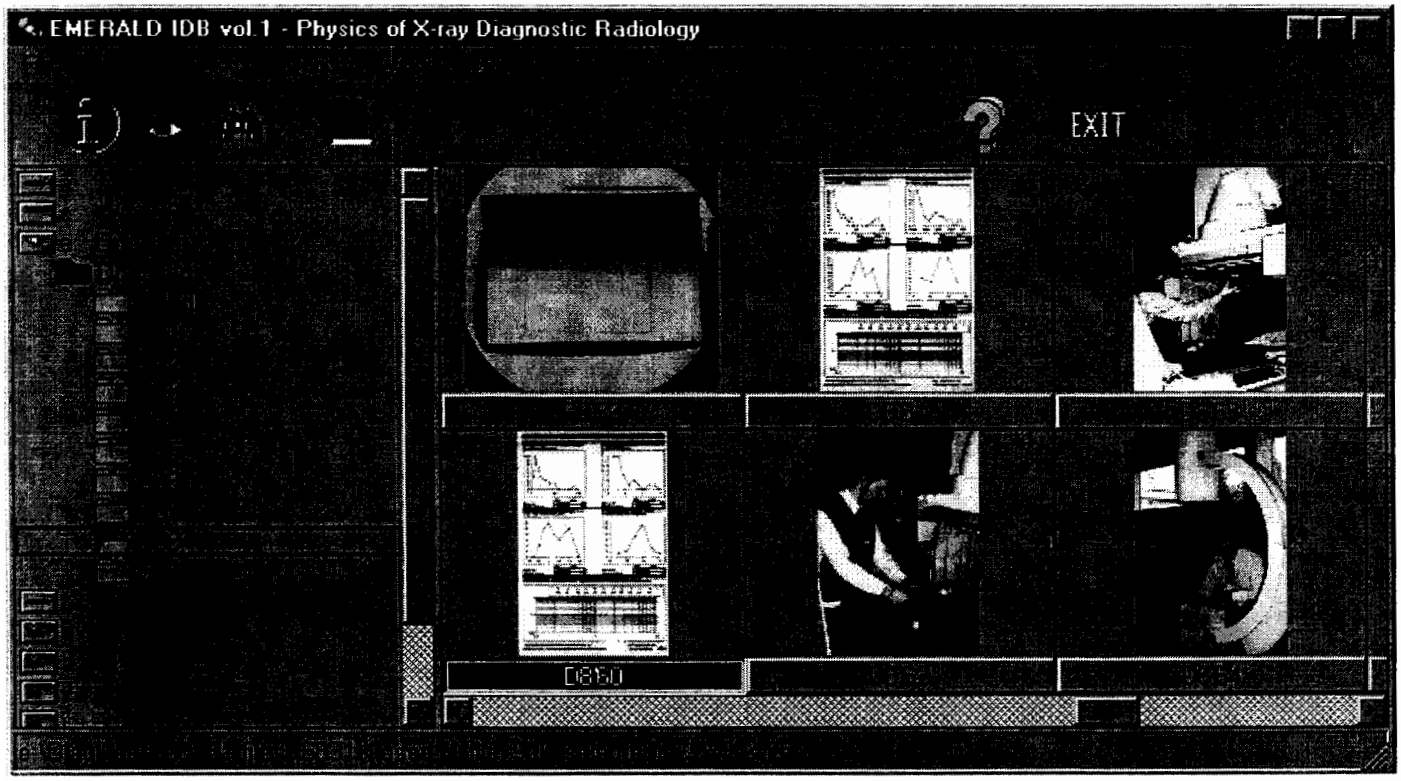

Fig.1 Graphical interface of the EMERALD Image Database with Thumb+Plus browser. An example from Image Directory 8, corresponding to Chapter 8 (Fluoroscopic Equipment - the task on image quality assessment) of the training module on Physics of X-ray Diagnostic Radiology.

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OPTIMISATION OF PATIENT AND STAFF EXPOSURE IN INTERVENTIONAL CARDIOLOGY

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Abstract

The Council Directive of the European Community 97/43/Euratom (MED) deals with the health protection of individuals against dangers of ionising radiation in relation to medical exposure, and also focuses attention at some special practices (Art. 9), including interventional radiology, a technique involving high doses to the patient.

The paper presents the European approach to optimisation of exposure in interventional cardiology. The DIMOND research consortium (DIMOND: Digital Imaging: Measures for Optimising Radiological Information Content and Dose) is working to develop quality criteria for cineangiographic images, to develop procedures for the classification of complexity of therapeutic and diagnostic procedures and to derive reference levels, related also to procedure complexity. DIMOND project includes also aspects of equipment characteristics and performance and content of training in radiation protection of personnel working in interventional radiology field.

1. Introduction

The number and complexity of diagnostic and interventional procedures (IR) done in the medical practice have grown enormously, in particular in the last ten years, due to the availability of more suitable materials necessary to the procedures, and to the availability of the modern diagnostic units, either using X-rays or US, MR. However, the vast majority of these procedures are performed in a radiological room under fluoroscopy, simply because the vascular are the leading indications. Today, interventional radiology reduces the need for many traditional interventions, particularly surgery, therefore reducing the overall discomfort and risks for the patient compared to the traditional methods.

Due to the potential of high patient and staff doses and to the observed deterministic injures, after long fluoroscopic interventional procedures, the Council Directive 97/43/Euratom of 30 June 1997 includes this practice in the art. 9 of the 'Special practices'.

The paper presents the European approach to optimisation of exposure in interventional cardiology and some of the results obtained by the DIMOND research consortium (DIMOND = Digital Imaging: Measures for Optimising Radiological Information Content and Dose). DIMOND group is working in the development of quality criteria for cineangiographic images. Also procedures for the classification of complexity of therapeutic and diagnostic procedures are studied together with the proposal of reference levels, also related to procedure complexity. DIMOND project includes also aspects of equipment characteristics and performance, staff and patient dosimetry and content of training in radiation protection for personnel working in interventional radiology.

2. Methods and results

2.1. Image quality criteria

An important aspect of optimisation strategy is the definition of methods for image quality assessment. The approach of EC guidelines on 'quality criteria for radiographic images' was assumed

as a model for the implementation of similar methodology for IR images. DIMOND has developed a preliminary set of quality criteria for coronary angiography images (table I). The quality is assessed as a visibility level of important anatomical and, also, pathological markers. Two pilot trials have been conducted on a set of 15 studies, obtained in 4 centres in Greece, Italy and Spain. Each study has been analysed by 6 independent cardiologists adopting a scoring system for the quantitative assessment of image quality. The preliminary experience indicates that criteria can be translated into a scoring system that yields reproducible data in most instances.

Table I. Example of quality criteria for left coronary angiography images based on the visibility of anatomical markers

LEFT CORONARY ANGIOGRAPHY

Image criteria

1. Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
2. Arms should be raised clear of the angiographic field and the spine should appear as less as possible.
3. Visually sharp reproduction of vessel walls.
4. Simultaneous and full opacification of the vessel lumen at least until the first critical lesion (70% by visual estimation).
5. Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
6. Visually sharp reproduction of the origin, proximal, mid and distal portion of the Left Anterior Descending and Circumflex arteries, in at least two orthogonal views.
7. Visually sharp reproduction of the side branches > 1 mm of the Left Anterior Descending and Circumflex arteries in at least two orthogonal views; the origin should be seen in at least one projection.
8. Visually sharp reproduction of the lesions in vessels > 1 in at least two orthogonal views.
9. Visualisation of collateral circulation when present.
10. When criteria 6-9 have been fulfilled, avoid extra projections (mainly LAO semiaxial).

2.2. Patient exposure: reference level and complexity index

Reference level (RL) is a powerful instrument for optimisation in medical exposure and DIMOND is trying to introduce it for interventional cardiology. But, taking into account that in IR the patient pathology drives the procedure complexity, RL has to be take into account, together with other factors (such as the body mass index) some of the complexity factors affecting the procedure.

Table II. Mean fluoroscopy time, number of frames and dose-are product (DAP) measured in some European centre.

Interventional cardiology procedure and centre	Fluoroscopy time (min)	N°. of frames	DAP ($Gycm^2$)
CAD	**4.1 ± 3.6**	**1093 ± 446**	**45 ± 28**
- Greece I	3.6	1596	54.6
- Greece II	9.1	1715	124.2
- Italy	4.1	748	38.0
- Spain	6.7	918	48.6
PTCA	**13.8 ± 8.5**	**1135 ± 545**	**73 ± 28**
- Greece I	11.1	1414	54.6
- Greece II	16.0	1702	124.2
- Italy	15.1	908	73.3
- Spain	19.8	995	64.3

From a sample of Coronary angiography (CA) and Percutaneous Transluminal Coronary Angiograplasty procedures (PTCA) procedures collected in 4 centres of three European Countries, preliminary reference levels (RL) have been derived expressed in term of DAP, fluoroscopy time and number of frames (table II). Difference between centre are evident and the evaluation of procedures complexity is necessary in order to explain such differences.

A index of pathology severity allows to derive RL as a function of pathology, helping a better evaluation of the optimisation level of the practice in an installation. As an example, in Udine hospital, a partner of DIMOND consortium, the correlation of severity of cardiovascular pathology

with technical parameters used for the PTCA procedures was evaluated. The relationship between clinical and technical factors (CF) vs. fluoroscopy time and dose area product (DAP) was examined for 402 random PTCA procedures. Good correlation was found with: number and type of lesions treated, use of double wire or double balloon technique, ostial stenting and bifurcation stenting techniques, simple stenting , occlusion of vessel for more than 3 months, the presence of moderate vessel tortuosity (one bend > 90°), severe tortuosity (two or more bends > 90°) and IVUS (intravenous ultrasonography) use. Based on the relative weight observed in the multivariate analysis a complexity index (CI) was derived. For a practical application the procedures were divided in three groups according with different grades of complexity taking into account only: vessel occlusion ≥ 3 months, ostial and bifurcation stenting, and severe tortuosity (two or more bends > 90°) factors. Fig 1 shows the mean fluoroscopy time and DAP of the 3 groups of PTCA defined: simple, moderate and complex procedure. Further studies in different centres can demonstrate the applicability of this approach with the purpose to derive reference levels, complexity dependent, for IC and others frequent IR procedures.

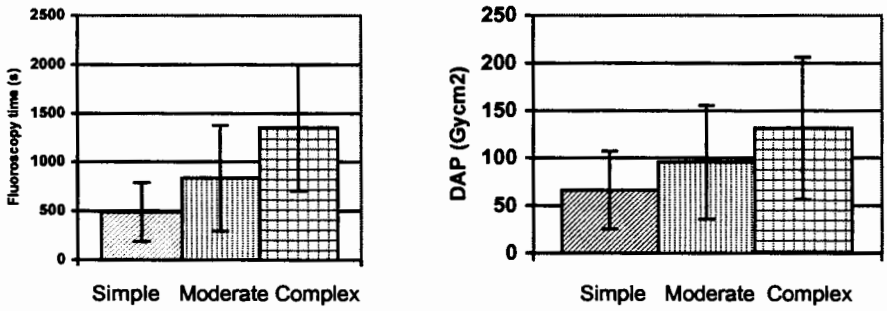

Figure 1. Maen Fluorosocpy time and DAP for simple, moderate and complex PTCA procedures

2.3. Staff exposure

In interventional radiology performed with fluoroscopic systems, where body exposure is not uniform and where part of the body is protected by lead apron or other specific mobile screens, the evaluation of effective dose is difficult and affected by high uncertainties [5, 18, 22]. Published dose data have been analysed and converted in effective dose adopting the dosimetric model proposed by Niklason [18]. The protocol is applicable when two dosimeters are worn over the apron at the neck level and under the apron at the waist level or when a single dosimeter is worn over the apron at the neck level. Table III report the effective dose to cardiologist (first operator) and nurse or technician per procedure. When available, dose from diagnostic (CA) and therapeutic (PTCA) procedures are reported. For cardiologist, effective doses per procedure from 0.2 to 18.8 are reported, with a mean values of 4.7 μSv/procedure. Only Vañó and Steffenino report effective doses of 18.8 and 15.1 μ Sv/procedure respectively. In these last two cases, it seems that the presence of cardiologists in training are the main cause of these high doses.

Table III. Effective dose to cardiologist (or first operator) and nurse/technician evaluated in different cardiac centre.

Reference	Effective Dose (μSv/procedure)	
	Cardiologist	Nurse
Vañó et al., 1998 [27]	18.8	
Padovani et al., 1998 [23]	2.2 (CA) - 8.8 (PTCA)	1.5 (CA) - 3.0 (PTCA)
Folkerts et al., 1997, [7]	2.0	
Li et al., 1995 [16]	8.0	2.0
Watson et al., 1997 [28]	1.8	1.4

Zorzetto et al., 1997 [33]	3.7	
Steffenino et al., 1996 [26]	15.1	3.7
DIMOND, Spain, 1999	2.2 (CA) - 4.4 (PTCA)	0.6 (CA) - 1.1 (PTCA)
DIMOND, Italy, 1999	0.5 (CA) - 1.0 (PTCA)	0.3 (CA) - 0.6 (PTCA)
DIMOND, Greece, 1999	1.0 (CA) - 2.0 (PTCA)	0.6 (CA) - 1.1 (PTCA)

3. Conclusions

The DIMOND approach to interventional cardiology, that will be refined in the context of DIMOND III (2000-2003) project, will give a methodology and a complete set of instruments for the evaluation of the optimisation level in an installation including: quality criteria for images and reference levels as a function of procedure complexity.

From the reported staff dose data the following comments and suggestions can be derived:

- many variables affect staff exposure: distance, direction, use of protective screens, procedure, skill, training, equipment performance, etc
- the analysis of personal dosimetry data is difficult when: the dosimeters are not always worn all the time by operators or the dosimeters are worn in different or wrong positions
- the normalisation of the personal dose to workload, expressed in terms of number of procedures or dose-area product, allows a straightforward comparison between facilities and helps to identify those clinicians who are not taking effective radiation safety precautions.

In interventional radiology, Dose constraints (ICRP 60 and EC Directive 96/29, art. 7) can be conveniently expressed them in terms of effective dose per procedure or effective dose per unit of dose-area product.

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CONTRIBUCIÓN DEL PROYECTO ARCAL XX/OIEA AL MEJORAMIENTO DE LA SEGURIDAD RADIOLÓGICA EN LAS PRÁCTICAS MÉDICAS

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Abstract

The objectives of the ARCAL XX Project: "Guidelines on Control of Radiation Sources" (1997-2000) are to promote an effective control of the radiation sources used in medicine, industrial and research applications, harmonising and updating existing procedures within Latin American, adopting the International Basic Safety Standards, in order to avoid unnecessary expositions limiting the probability of accidents occurrence. Nine countries participate with experts in the development of guidelines based in the regional experience. The guidelines content Radiological Safety Requirements, Guide for Authorisation Application and Inspections Procedures. In this moment, there are guidelines in Radiotherapy, Nuclear Medicine and Diagnostic Radiology. The implementation of these guidelines will improve the effectiveness of regulatory control of radiation sources in Latin American and the radiological protection in aspects of occupational, medical, public and potential exposure. This document presents the experience in the development of these guidelines and their contribution for elaborating national regulations in the medical practices.

Resumen

Los objetivos del Proyecto ARCAL XX: "Directrices para el control de Fuentes de Radiación" (1997-2000) son promover un efectivo control de las fuentes de radiación usadas en medicina, industria e investigación, harmonización y actualización de procedimientos existentes dentro de América Latina, adoptando las Normas Básicas Internacionales de Seguridad a fin de evitar exposiciones innecesarias limitando la probabilidad de ocurrencia de accidentes. Nueve países participan con expertos en el desarrollo de directrices basadas en la experiencia regional. Las directrices contienen Requisitos de Seguridad Radiológica, Guía para solicitar Autorizaciones y Procedimientos de Inspección. En este momento hay directrices en Radioterapia, Medicina Nuclear y Radiología Diagnóstica. La implementación de estas directrices mejorará la efectividad del control regulatorio de las fuentes de radiación en América Latina y la protección radiológica en aspectos de exposición ocupacional, médica, pública y potencial. Este documento presenta la experiencia en el desarrollo de estas directrices y su contribución para la elaboración de regulaciones nacionales en las prácticas médicas.

INTRODUCCIÓN

En 1985, debido a la inquietud de los países del Grupo Andino: Bolivia, Colombia, Ecuador, Perú y Venezuela se da inicio a las actividades de cooperación técnica en materia nuclear en el marco del Programa ARCAL (Acuerdo Regional de Cooperación para la Promoción de la Ciencia y Tecnología Nucleares en América Latina y el Caribe, como se denomina actualmente), con la participación inicial de 10 países de la región.

El Programa ARCAL fue concebido desde sus inicios como un primer paso en el camino de la promoción de la cooperación regional en el uso pacífico de la energía nuclear, en particular de las aplicaciones nucleares, y sobre esta base, lograr una integración regional que permitiese resolver problemas tecnológicos comunes a los países de la región.

Un importante Proyecto fue el de "Protección Radiológica" (ARCAL I), el cual se llevo a cabo entre 1985 y 1993. Aquí se determinaron las necesidades inmediatas de protección radiológica en la región y

se mejoró, en parte, las condiciones de protección radiológica existentes en las instalaciones, adicionalmente se desarrollaron actividades regulatorias.
Los Coordinadores del Proyecto ARCAL I diseñaron los siguientes 2 Proyectos que serían una continuación de éste. Tal es así que se desarrolla el Proyecto ARCAL XVII (1994 – 1996) denominado "Estructura Normativa y Organización Regulatoria", con el objetivo de promover la adopción de una norma básica de protección radiológica desarrollada sobre la base de las ultimas recomendaciones internacionales en el tema y promover el desarrollo de estructuras regulatorias que permitan cumplir las funciones esenciales de su misión.

Desde 1997 y por un período de 4 años se desarrolla el Proyecto ARCAL XX: "Directrices para el Control de Fuentes de Radiación" con el objetivo de promover un desarrollo armónico en la región a fin de garantizar un efectivo control de las fuentes de radiación para evitar exposiciones innecesarias y limitar las posibilidades de accidentes, adoptando las nuevas orientaciones de las Normas Básicas Internacionales de Seguridad. [1]

EL PROYECTO ARCAL Y LOS RESULTADOS ESPERADOS

A diferencia de los anteriores Proyectos, en ARCAL XX solamente participan los países que cuentan con la infraestructura básica necesaria para llevar a cabo el control de fuentes de radiación, tal como: Autoridad Competente establecida, Reglamentos y Normativas básicas, Inventario de Fuentes de Radiación, Programa de Licenciamiento e Inspección de instalaciones, Programa de Emergencias Radiológicas, Servicios esenciales en Protección Radiológica (monitoreo ambiental, dosimetría personal y ocupacional, etc.) y Actividades de Capacitación en Seguridad Radiológica. Estos países son: Argentina, Brasil, Chile, Cuba, Ecuador, México, Perú, Uruguay y Venezuela.

Los resultados esperados para el cumplimiento del objetivo principal del Proyecto son:

a) Evaluación de la eficacia de los sistemas regulatorios,
b) Armonización y actualización de criterios de autorización e inspección en aplicaciones médicas, industriales y de investigación,
c) Difusión de información sobre seguridad radiológica.

A partir de ello se obtendrá lo siguiente:

a) Evaluación de los Sistemas de Control de Fuentes de Radiación Ionizante a través de Indicadores de Desempeño,
b) Elaboración de "Guías Reguladoras de Seguridad Radiológica", las cuales contendrán:
   i) Requisitos de Seguridad Radiológica
   ii) Guía para Solicitar Autorización
   iii) Procedimiento para la Realización de Inspecciones
c) Divulgación en INTERNET de las actividades más importantes realizadas en el marco de ARCAL y del Organismo Internacional de Energía Atómica en el campo de la Protección Radiológica en la región,
d) Publicación del Boletín ARCAL sobre Protección Radiológica.[2]

[1] ACTIVIDADES REALIZADAS

A fin de planificar y evaluar las actividades de ARCAL se establecieron las Reuniones de Coordinadores de Proyecto, las cuales se han llevado a cabo en Caracas, Venezuela (1997), Goiania, Brasil (1997), La Habana, Cuba (1998) y Bariloche, Argentina (1999), hasta el momento.

El mecanismo establecido permitió que cada país se encargue, por lo menos, de coordinar una actividad. Para elaborar los documentos, los expertos de un país elaboraron un primer borrador tomando en cuenta su experiencia en el tema y los aportes de los demás países. Posteriormente este documento es remitido a todos los países para opinión y en reuniones de expertos del mismo tema se concluye una versión que es nuevamente remitida a los países. Seguidamente un Comité de Revisión se encarga de revisar la redacción de los documentos y homogeneizar el rigor técnico y los términos empleados. Este Comité está integrado por los Coordinadores de Proyecto de Argentina, Cuba, México, Perú y Venezuela. Finalmente el documento es sometido a aprobación en la Reunión de Coordinadores de Proyecto.

De esta forma se han elaborado los siguientes documentos:

[2] Instrucciones para la elaboración de documentos
[3] Manual del Inspector
[4] Evaluación de los Sistemas de Control de Fuentes de Radiación a través de Indicadores de Desempeño
[5] Guía práctica para la rápida identificación de fuentes radiactivas y equipos que las contienen
[6] Guías Reguladoras de Seguridad Radiológica para las prácticas de:
1. Radiografía Industrial
2. Radioterapia
3. Medicina Nuclear
4. Radiodiagnóstico Médico
5. Irradiación Gamma
6. Prospección Petrolera
7. Aplicaciones Industriales de Fuentes no Selladas

Otras actividades desarrolladas son la página Web del Proyecto: www.arcalxx.org.pe y la edición del Boletín ARCAL "Protección Radiológica", el cual se edita desde 1991 y hasta la fecha se han distribuido 61000 ejemplares a mas de 40 países en forma gratuita.

Al finalizar este Proyecto el Organismo Internacional de Energía Atómica habrá invertido mas US$ 400,000 para llevar a cabo todas las actividades programadas, y los países habrán contribuido con expertos y el apoyo logístico interno para llevar a cabo las actividades. [2][3][4]

[7] DOCUMENTOS PARA LAS PRÁCTICAS MÉDICAS

Las Guías Reguladoras de Seguridad Radiológica para las prácticas de Radioterapia (Teleterapia y Braquiterapia), Medicina Nuclear y Radiodiagnóstico Médico han sido preparadas por separado. Estas a su vez contienen los siguientes documentos:

[8] **Requisitos de Seguridad Radiológica.-** Aquí se establecen los aspectos técnicos que se deben cumplir en cada práctica, como son:
a. Requisitos Administrativos: Autorización Institucional, Autorizaciones y Acreditaciones Personales, Entidades de Servicio, Renovación de Autorizaciones, Suspensión o revocación de Autorizaciones, Cese en el uso de fuentes de radiación ionizante, Comercialización e importación de fuentes de radiación ionizante.
b. Requisitos de Protección Radiológica
c. Requisitos de dirección y organización: Personal y capacitación.
d. Seguridad radiológica de las instalaciones: Requisitos de diseño de fuentes y/o equipos, Diseño de ambientes del Servicio, Requisitos operacionales.
e. Exposición Ocupacional: Responsabilidades y condiciones de servicio, Clasificación de zonas de trabajo, Dosimetría personal, Vigilancia radiológica de las zonas de trabajo, Dispositivos de protección radiológica, Investigación y seguimiento. Registros.

f. Exposición Médica: Responsabilidades, Justificación, Optimización, Calibración, Dosimetría Clínica y Garantía de Calidad, Investigación en exposiciones médicas accidentales y Registros.
g. Exposición del público: Responsabilidades, Control de visitantes y Vigilancia radiológica de la exposición del público.
h. Exposición potencial

Adicionalmente se prepararon Anexos sobre: Dotación y Requisitos de personal, Contenido Típico de un Programa del Curso de Seguridad Radiológica, Responsabilidades del Personal, Contenido de un Programa Típico de Seguridad Radiológica y Garantía de Calidad, Comité de Seguridad Radiológica y Garantía de Calidad, Contenido de un Informe de Levantamiento Radiométrico, Niveles Orientativos, Control de Calidad: pruebas mínimas, frecuencia y requisitos de desempeño.

[9] **Guía para Solicitar Autorización.-** Aquí se detallan los aspectos técnicos y procedimiento a seguir por los usuarios de radiación ionizante ante la Autoridad Reguladora para obtener las Autorizaciones Personales o Institucionales (construcción u operación). También se establece el procedimiento a seguir por las Entidades de Servicio y cuando cesa la operación de una instalación.

[10] **Procedimiento para la realización de Inspecciones.-** Se presentan las listas de chequeo que deben ser utilizada por el Inspector de la Autoridad Reguladora. Hay listas de chequeo para cada práctica y a su vez para las diferentes modalidades, por ejemplo se ha preparado listas de chequeo en Radiodiagnóstico Médico para Radiografía Convencional, Mamografía, Fluoroscopia y Tomografía Computarizada, incluyéndose la Radiología Intervensionista.

Las Guía Reguladoras contienen también: Introducción, Glosario, Referencias y Lista de Participantes. Los demás documentos son también de gran utilidad para estas prácticas. Por ejemplo, la Guía para una rápida identificación de fuentes radiactivas y equipos que las contienen será utilizada cuando se presenten emergencias, ya que mediante este documento se puede identificar de que fuente y/o equipo se trata, y se podrá conocer sus características principales a fin de facilitar la labor de recuperación.

[11] IMPORTANCIA DEL PROYECTO

Los documentos elaborados en el Proyecto están permitiendo actualizar los procedimientos y en especial las Normas de las Autoridades Reguladoras ya que éstos son tomados como referencia principal. Adicionalmente se ha tomado en cuenta los documentos que se vienen elaborando en el OIEA e inclusive algunos expertos de la región participan en la elaboración de éstos documentos. Por otra parte, los documentos de ARCAL han sido presentados a otros Proyectos Regionales (AFRA y RCA) como un ejemplo a seguir.

Estos documentos están permitiendo un mejoramiento de las condiciones de seguridad radiológica de las prácticas y en especial se está abordando el tema de las exposiciones médicas con lo cual se logra proteger al paciente adecuadamente. Adicionalmente, se ha tomado en cuenta la experiencia de los países y se está logrando un consenso en su aplicación debido a las características de la región en donde se comparte, además del idioma, muchas características comunes.

Se espera capacitar a personal de las Autoridades Reguladoras de la región mediante cursos y entrenamientos en otro Proyecto que será consecuencia de ARCAL XX.

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Table 1

EVALUATION OF PATIENT SKIN DOSE EQUIVALENT DUE TO DIAGNOSTIC PROCEDURES WITH X-RAYS IN LAGOS STATE NIGERIA

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ABSTRACT

This paper reports the study of Patient Skin Dose Equivalents in Lagos State, Nigeria, as one of the strategies of patient protection and x-ray procedure quality assessment. 13 most frequent x-ray diagnostic procedures were studied. These were chest, skull, cervical spine, lumbosacral spine, sinusis, pelvis, plain abdomen, shoulder, foot, hysterosalpingography, intravenous urography, barium meal and barium enema. 1977 procedures were monitored for a period of 12 months in both private and public hospitals carefully selected from all over the state. The results obtained compared favorably well with those from similar studies reported in the literature. The slight differences observed have been ascribed to variations in the patient anatomy, exposure conditions and choice of radiographic parameters.

Technical Topic Session: Research Relating to Radiological Protection in Medicine.

1. INTRODUCTION

The main radiation protection problem in the diagnostic applications of x-rays is the unnecessary irradiation of patients and staff. Exposures to ionizing radiation and the associated health hazards necessitate the need for justification, optimization and respect of norms as recommended by the relevant international organizations [1]. Patient exposures in most cases are justified having taken account of alternative diagnostic methods using non-ionizing radiation [2]. Optimization implies reduction of patient dose to minimum possible while still obtaining all the necessary diagnostic information according to the ALARA principle.

Evaluation of Patient Skin Dose Equivalent (PSDE) is an optimization process intended for monitoring and assessment of performance within a department as part of dose reduction and patient protection strategies. PSDE is useful in the assessment of the potential harms from a particular procedure and for intercomparison of quality and standards between departments at national and international levels. The various direct and indirect methods of patient dosimetry exist in the literature [3,4,5]. PSDE monitoring is of particular importance in third world countries where the larger percentage of the radiation facilities are old, many of them not regularly serviced and the quality control and recalibration of the electric, mechanical and dosimetric performance parameters are almost non existent as in the developed countries.

This paper reports the PSDE from 13 most frequent x-ray diagnostic procedures in Lagos state, Nigeria. Lagos, being the economic and the industrial nerve center of the country, is the most densely populated city in the West African subregion. The number of private hospitals in the state is far greater than public and they are of varying sizes and standards. Some of the public and private hospitals have been selected for this study. The results obtained were compared with similar studies reported in the literature. The goal is to improve the quality of radiodiagnostic procedures, the quality being defined in terms of qualitative image vis-à-vis the dose to patient.

2. MATERIALS AND METHODS

PSDE were monitored for a period of 12 months in 10 different public and private hospitals distributed all over Lagos state. The criteria for selection of hospital included good representation of type of diagnostic procedures studied, the geographical location, how busy the hospital is and the facilities available. The 13 procedures studied were chest, skull, cervical spine, lumbosacral spine (LSS), sinusis, pelvis, plain abdomen, shoulder, foot, hysterosalpingography (HSG), Intravenous Urography (IVU), Barium Meal (BM) and Barium Enema (BE). 1977 procedures were monitored out of which 1485 were common and 492 were special procedures.

Thermoluminescence Dosemeter (TLD) LiF chips were placed one on each side and one at the central axis of the rectangular x-ray beam on the patient skin. From reading the chips the average PSDE for each exposure was determined. The TLD reader was Tolede 654 from Vinten U.K. at the Federal Radiation Protection Service. The system had been pre-calibrated at the dosimetry laboratory of IAEA in Seibersdorf, Austria. A patient radiological examination conditions and radiological parameters.

3. RESULTS AND DISCUSSIONS

The number of exposures, the range of the PSDE and the mean values for the various procedures monitored are summarized in table 1 below. (Check the attachment for the table). The ranges of the PSDE from the literature are contained in the last column for comparison. The PSDE recorded cover a wide range and vary with patients. This observation is expected because each patient is unique in anatomy, age, weight, illness and exposure conditions. Patient dose depends on type of procedure, beam size or the volume of tissue in the beam, patient positioning as well as radiological parameters such as KV, mAs, type and speed of film, use of intensifier and grid, age, type and the output of the x-ray facility. These technical and patient anatomical difference have been identified to account for the wide PSDE ranges. Some procedures such as LSS, HSG, IVU, BM and BE gave PSDE values which are multiples of the means annual background dose limit. The range of the PSDE obtained compared with those by Roger R.T. [6] and the means PSDE values by Shrimpton et al.[7] show a good agreement. The slight differences could be attributed to the patient anatomical and exposure parameter differences.

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FREQUENCY OF CHROMOSOME ABERRATIONS IN PERIPHERAL BLOOD LYMPHOCYTES FROM WORKERS OCCUPATIONALLY EXPOSED TO DIAGNOSTIC X-RAYS

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Abstract

Peripheral blood lymphocytes of 150 medical diagnostic X-ray workers, were examined for the frequency of acentric and dicentric chromosome aberrations (CAs). These occupationally exposed individuals, consist of 108 male and 42 females with mean age and duration of work of (34.2 ± 8.1) and (9.6 ± 6.7) years, respectively and all were routinely monitored with film badges. None of them had ever exceeded the permitted radiation limit for occupationally exposure recommended by the ICRP. The results are compared with those of 58 matched donors without radiation history as the control group. At least 100 metaphases were scored for each individual and the aberrations considered were acentric (ac) and dicentric (dic) which are the most important aberrations used for cytogenetic dosimetry.The data include 18,320 and 9000 cells scored for CAs in the workers and controls, respectively. Our results showed higher frequencies of dicentrics as well as acentrics in the workers than in the controls ($P<0.05$). The mean frequency of acentric and dicentric aberrations for the workers and control were: (ac) 2.85 /100 cells and 1.12/100 cells, and (dic) 1.03×10^{-3} and 0.33×10^{-3}, respectively. Although the mean frequency of CAs in the male workers were slightly more than in the female workers, however, no obvious trend of increased aberrations as a function of either duration of employment or age were noticed.

1-Introduction

Several studies on the induction of CAs by diagnostic X-rays have been published (UNSCEAR 1969). Diagnostic and therapeutic uses of ionizing radiations make the largest man-made contribution to the population dose (UNSCEAR, 1982). In diagnostic radiology it is intended that the desired information is obtained with minimum exposure of the subjects and with the least risk to the technical personnel. medical workers thus constitue the group most consistently exposed to low doses of ionizing radiations (1). CAs especially dicentrics induced by ionizing radiation in human lymphocytes offers a useful means of radiation exposure (2). Hagelstrom et al.(1995) who tested a group of workers occupationally exposed to chronic low level ionizing radiation, demonstrated a significant increase in the level of CAs(3). Jha AN et al.(1991) showed higher frequencies of dicentrics as well as acentrics in the personnel handling diagnostic X-ray machines, than in the normal controls(4). Lloyd et al.(1980) also reported elevated levels of unstable CAs in the workers occupationally exposed to ionizing radiation(5).Stewart and Sanderson (1961) demonstrated chromosomal abnormalities in individuals receiving less than 0.3 and 2.0 rad of diagnostic X-rays(6).Norman et al.(1964) found about 0.77% dicentrics in lymphocytes of radiation workers exposed to a cumulative dose of 10-25 rad during the period of their employment(7). Bigatti et al.(1988) showed an increased frequency of chromosomal aberrations, including dicentrics, in 3 groups of hospital workers who were exposed to very low levels of X- or γ-rays(8). CAs have a major role in the developed of neoplasms and hereditary defects in humans. This proposal is an approach to study the formation of CAs induced by ionizing radiation in radiation workers. In this study we examined the frequency of acentric and dicentric aberrations in 150 workers occupationally exposed to diagnostic X-rays. This is important as significantly elevated levels of such aberrations may be found in peripheral blood lymphocytes of radiation workers who are exposed within the occupational limits recommended by the ICRP.

2-Materials & Methods

2.1. Research subjects

A group of 150 workers occupationally exposed to diagnostic X-rays, was tested. The group consisted of 108 male and 42 female workers with mean age and duration of employment of 34.2±8.1 (range 20-55) and 9.6±6.7 (range 1-28) years. Cytogenetic findings of the whole group were compared with those obtained in a control group of 58 matched blood donors, healthy and without radiation history. Mean age for the control was 35.6±7.6 (range 21-57) years.

2.2. Lymphocyte cultures

The cultures were set up by adding 0.5 ml of heparinized blood to 4.5 ml RPMI 1640 medium (Gibco BRL), supplemented with 20% fetal calf serum (Gibco BRL), antibiotics, phytohaemagglutinin and L-glutamin and also (BrdU) was also added to a final concentration of 5 µg/ml. Colchicine(Fluka) was added to a final concentration of 0.5 µg/ml 2 h before the end of the incubation. The cultures were harvested after 48 h of incubation, by centrifugation, suspended in hypotonic solution(0.075 M KCl), incubated 20 minutes at 37°c and fixed in three changes of methanol :acetic acid (3:1). Cell suspensions were dropped on wet, cold slides and dried. Then the slides were routinely stained with Giemsa (9). At least 100 metaphases were examined for each individual. Chromosome aberrations: dicentrics, rings and acentrics, were scored exclusively from first-division metaphases.

2.3. Statistical evaluation

The frequency of unstable chromosome aberrations in the lymphocytes of the subjects and controls were compared using student's t-test. The influence of age and duration of employment was tested by the regression method.

3- Results

The results of chromosomal analyses in the workers and controls are presented in Table 1. The frequency of both dicentrics and acentrics are significantly higher in the workers than in the controls ($P<0.05$). Among 150 individuals studied, dicentrics were observed in 6 cases.

Table 1:

The frequency of chromosomal aberrations in the control and occupationaly exposed workers.

Group	subjects	Age(y) M±SD Range	Duration of work(y) M±SD Range	cells scored	Dicentrics/ cell$\times 10^{-3}$ ±SD	Acectrics/ 100 cells ±SD
Radiation workers	150	(34.2±8.1), 20-57	(9.6±6.7) , 1-28	18320	1.03±0.42	2.85±0.34
Controls	58	(33.6±7.2), 20-55	-	9000	0.33±0.25	1.12±0.26

The frequency of CAs in the workers and controls are shown in the figure 1.

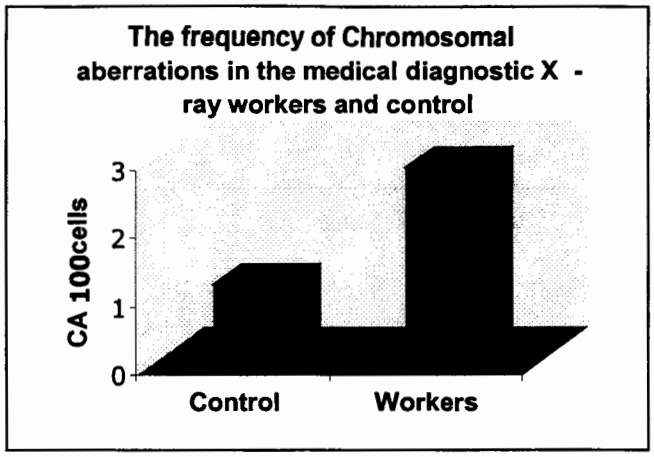

Fig. 1

In order to test the difference between the frequency of CAs in male and female workers, the survey group was divided due to their sexes. The results of chromosomal analyses in these 2 groups are presented in Table 2.

Table 2:

The frequency of chromosomal aberrations in control and male and female workers.

Group	No. of subjects	Age±SD(y)	Duration of work (y)	cells scored	CAs/100cells ±SD
Male workers	108	34.9±7.90	10.34±6.85	12275	3.03±0.32
Female workers	42	32.2±8.53	7.9±6.20	6045	2.62±0.29
Male controls	30	36.8±6.38	-	4650	1.21±0.61
Female controls	28	33.5±7.42	-	4350	0.97±0.42

The mean frequencies of CAs were higher in the male workers than in the female workers, but it was statistically not significant. Apply the regression method, no significant relationship was found between the duration of employment , age and the chromosomal findings in male and female workers.

4-Discussion

Several authors published data on the higher incidence of CAs in workers occupationally exposed to diagnostic X-rays, obtained by the conventional technique of evaluation of Giemsa-stained chromosomes (1).Increased frequencies of chromosomal aberrations are well known among occupationally exposed workers even at much below the permissible level of exposure. In the classical study on 200 nuclear dockyard workers (Evans et al., 1979), an elevated frequency of chromosomal aberrations was reported after 10 years of study. A dose-effect relationship was also observed on the basis of their accumulated dose (10). Similarly, Bauchinger et al. 1980, documented a higher frequency of dicentrics and acentrics in nuclear power plant workers, but without any dose-effect relationship (11). Our results show a significant increase in the number of both types of aberrations: acentrics and dicentrics, when compared with the control group of blood donors without radiation history. The present observation therefore supports the findings of other investigators. In the occupationally exposed individuals in the current study an increased frequency of acentrics was frequently noticed. Most cases of increased frequency of acentrics are known to involve relatively minor exposure to low doses or dose rates of X- and γ- radiations (12). Although in this study the numbers of acentrics and dicentrics were higher than in the control group ($P<0.05$), no significant differences were found between the numbers of aberrations and duration of employment and sex.

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ESTIMACIÓN DE DOSIS A PACIENTES DURANTE EXÁMENES RADIOLÓGICOS EN LA REPÚBLICA DE HAITÍ

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Abstract. The International Commission on Radiological Protection and the international organizations that co-sponsored *the International Basic Safety Standards for the Protection against Ionization Radiation and for the Safety of Radiation Sources* (BSS) –among them PAHO and WHO– recommended the use of investigation levels to provide guidance for medical exposures. In this work, entrance surface doses for several common diagnostic radiology procedure have been determined from exposure rate measurements and patient technique factors in seven "World Health Imaging System – Radiography" (WHIS-RAD) units, installed in public health services facilities of the Republic of Haiti. The results show the entrance surface doses below the guidance levels published in the BSS. Concomitant image quality measurements performed, however, indicate serious artifacts in the film processing, calling for the need of additional training of the technologists.

Introducción

Haití tiene una población de alrededor de 8 millones de habitantes. En los servicios públicos, se estima hay unos 20 equipos de rayos X. Entre 1993 y 1996 la Organización Panamericana de la Salud / Organización Mundial de la Salud (OPS/OMS), dotó al país de 11 equipos de radiografía del tipo "WHIS-RAD" – World Health Imaging System– Radiography, 7 de la firma Philips y 4 de la firma Bennett. Este equipo se caracteriza por tener un sistema de soporte en arco C que mantiene el receptor de imagen siempre alineado con el tubo de rayos X a una distancia fija de 1,4m, con una mesa flotante. El tubo de rayos X tiene un punto focal de menos de 1mm y una potencia de 24 a 30kWs. El generador es de alta frecuencia y funciona con baterías.[1]

Objetivo

El objetivo de este trabajo, es hacer una estimación de la dosis de entrada en la superficie del paciente (*DES*), utilizando las técnicas radiológicas recomendadas por la OMS (kVp y mAs) [2] y las tasas de exposición en aire medidas en 7 de estas unidades, para compararlas con los niveles orientativos de dosis publicados en las *Normas básicas internacionales para la protección contra la radiación ionizante y para la seguridad de las fuentes de radiación,* (NBS) [3] copatrocinadas por seis organismos

internacionales –entre ellos la OPS y la OMS– y publicadas (en castellano) por el Organismo Internacional de Energía Atómica (OIEA) en 1997. De acuerdo con los criterios de las NBS, se evaluó también la calidad de la imagen radiológica.

Métodos.

Durante las pruebas de aceptación de los equipos se verificó que todos cumplían con las especificaciones de la OMS.[1] Se midieron: el tamaño del punto focal, la exactitud del potencial, la congruencia del campo luminoso y el de radiación, la calidad de la imagen, la capa hemirreductora (CHR), la reproducibilidad y linealidad del generador, y la tasa de exposición en aire. Para las cuatro últimas medidas se usó un monitor de rayos-X (MDH Radcal-1015) y filtros de aluminio. De los valores de CHR medidos, se determinó que la filtración total de los equipos era de 3 mm de aluminio, de acuerdo con las especificaciones de la OMS. La calidad de la imagen se determinó radiografiando dos patrones de resolución espacial de pares de líneas, uno de alto contraste y otro de bajo contraste.

Se determinaron las *DES* para cada una de las técnicas recomendadas [2] por la OMS, utilizando un factor de conversión de 0.00877 para convertir de mR a mGy y corrigiendo por la geometría de medición.

Resultados

En la figura-1 se presentan la tasa de exposición y la CHR en función del potencial del tubo, medidas en cada una de las unidades. Las variaciones mínima y máxima de los valores obtenidos para la tasa de exposición son del orden de 5 y 19% a 70 y 53 kVp respectivamente y hay una variación de 5% para las CHR, independientemente de la energía del haz.

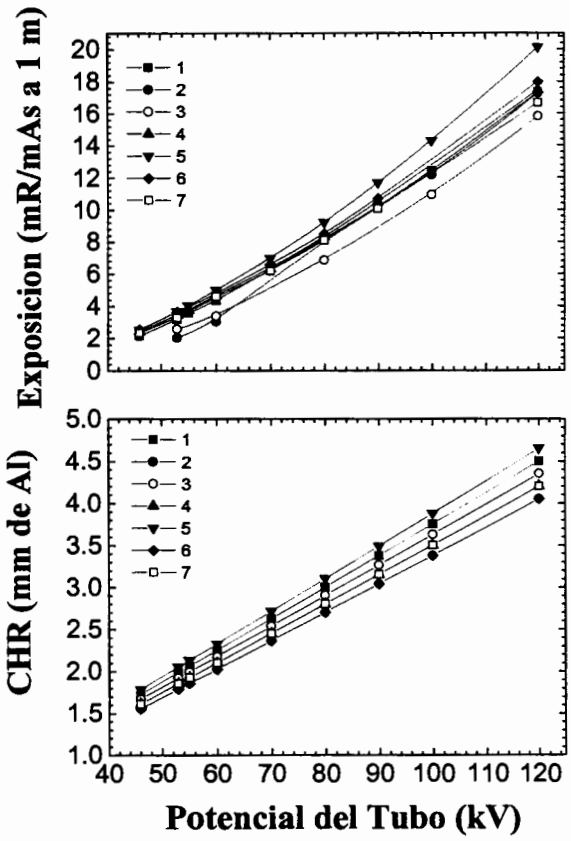

Figura-1. Tasa de exposición y CHR en función del potencial del tubo medidas en las 7 unidades WHIS-RAD

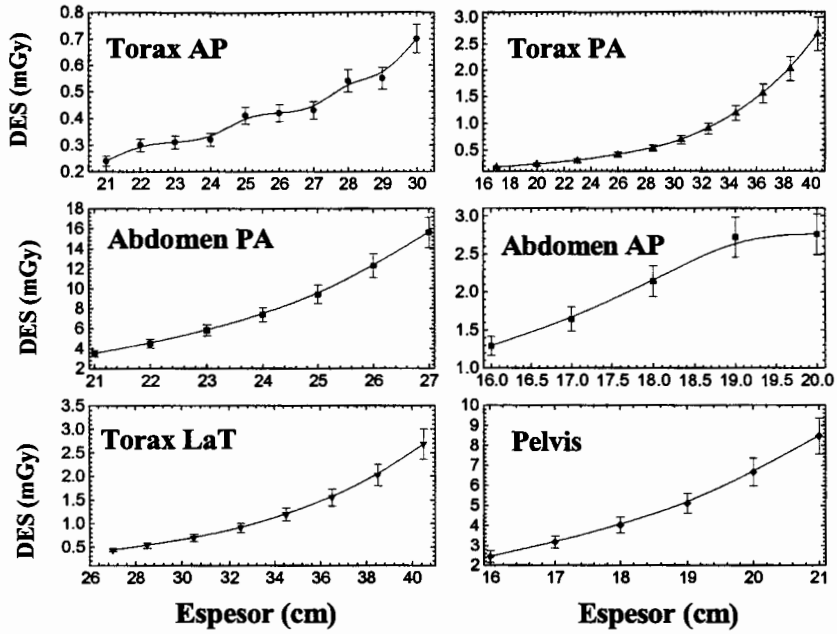

Figura-2. Dosis de entrada en la superficie del paciente en función del espesor del paciente para diferentes proyecciones radiográficas

En la figura-2 se presenta la variación de las DES promedio en función del espesor del paciente para 6 proyecciones radiográficas. Las desviaciones estándar varían entre 8 y 12%, independientemente de la técnica.

Tabla-1 Comparación de los valores de *DES* determinados en este trabajo, asumiendo un espesor del paciente de 20 cm y una anchura de 34.4 cm, con los reportados en las NBS.

Examen		*DES (mGy)*	
		NBS	HAITI
Tórax	PA	0.4	0.23 ± 11%
	AP		0.24 ± 7.7%
	LAT	1.5	1.19 ± 12%
Abdomen	AP	10	2.76 ± 9.7%
	PA		3.51 ± 9.7%
Cráneo	PA	5	3.01 ± 10.6%
	LAT	3	1.33 ± 10.6%
Pelvis		10	6.66 ± 10.6%

Tabla-2. Evaluación de la calidad de imagen en las unidades WHIS-RAD [Patrones de barras sobre el receptor de imagen: 0.1 mm Pb (AC) y 0.001 mm Pb (BC); 70 kV, 3.2 mAs]

Unidad	*Contraste**	*Resolución (pl/mm)*		*Revelado*
		AC	***BC***	
1	1.27	3.1	2	OK
3	0.71	4.0	2.2	OK
4	0.37	3.1	2.2	Artefactos
5	1.04	3.4	2.2	Artefactos
6	0.47	3.7	2.5	Artefactos
7	0.41	3.1	2.8	Artefactos

En la tabla-1 se presentan los valores de DES, con sus desviaciones estándar, obtenidos en este trabajo y los publicados en la literatura para un adulto típico

* Diferencia en la densidad óptica entre las áreas opaca y transparente en el patrón de barras de Pb.

Los resultados de la evaluación de la calidad de imagen se presentan en la tabla-2.

Conclusiones

Los valores presentados en la tabla-1 muestran que la dosis que recibe un paciente durante los exámenes radiológicos estudiados es más baja que los niveles orientativos publicados en las NBS. Sin embargo, los resultados de la tabla-2 indican que sólo dos instituciones producían placas radiográficas sin artefactos serios, factor que afecta significativamente la calidad de la imagen, y como consecuencia en las otras instituciones, la probabilidad de que el médico no haga una interpretación radiológica adecuada, lo cual implica la posible necesidad de repetir la radiografía y por tanto duplicar la dosis al paciente. Ello muestra la importancia de entrenar bien a los técnicos en los procesos de revelado como parte integral de un servicio de radiología.

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FLUOROSCOPÍA SIN INTENSIFICADOR DE IMAGEN

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Abstract

The objective of the present work was to evaluate the doses received by patients during fluoroscopy procedures carried out with an equipment without image intensifier. This evaluation is providing dose levels that our patients are presently exposed, as gives the data for epidemiological studies on risk estimate of cancer induction in patients exposed earlier when no image intensifiers existed. Diamentor M4 and E meters were used to measure the product dose-area (DAP). The data were acquired during barium enema, barium meal, barium swallow and histerosalpingographies. The measured values of DAP are considered high. This work intends to call the attention toward the optimization of the radiological protection in facilities that still use equipment without image intensifiers. While these equipment cannot be disabled, the patient exposure monitoring should be incentivated, and the application of radiological protection practices and programs of quality assurance should be of priority.

1. Introducción

En la actualidad, siguiendo las recomendaciones de la ICRP [1][2] y las directivas sobre protección radiológica del paciente [3], la preocupación por los métodos de optimización de la calidad de la información diagnóstica, el establecimiento de niveles de referencia y la reducción de dosis, tiene caracter prioritario. Esto sucede hoy, en tiempos en que equipos de rayos X sin intensificador de imagen ya fueron desactivados en paises desarrollados, pero continuan siendo usados en paises en desarrollo.

En los últimos años ha surgido gran interés por las exposiciones de pacientes en procedimientos fluoroscópicos diagnósticos e intervencionistas. Se trabaja intensamente en investigaciones sobre protección radiológica, niveles de exposición y recomendaciones al respecto [4][5][6][7][8] debido, en parte, a que la tecnología de los equipos es cada vez mas sofisticada. Por otro lado, al igual que en muchos países en desarrollo, en Brasil existen pocos estudios dosimétricos sobre fluoroscopía [9][10] y pocas recomendaciones y reglamentaciones sobre el asunto. Recién en junio de 1998 fue publicado el Reglamento Técnico "Portaria 453/98" del Ministerio de Salud de Brasil [11], que establece la obligatoriedad de la aplicación de programas de garantía de calidad, el uso de intensificadores de imagen en equipos fluoroscópicos, y la sustitución hasta 2003 de los actuales existentes sin este dispositivo.

Tanto en Europa como en Estados Unidos ya no es posible la dosimetria en fluoroscopía realizada con equipos sin intensificador de imagen, porque éstos fueron desactivados hace varias décadas. Sin embargo, en Brasil y otros países, todavía se puede medir exposiciones a pacientes en estos equipos. La evaluación de las exposiciones a pacientes irradiados de esta manera, proporcionará los niveles de dosis a los que nuestra población está actualmente expuesta, así como datos que permitan estimar dosis recibidas en el pasado en países donde equipos sin intensificador no existen mas, y datos para estudios epidemiológicos sobre estimativas de riesgos de inducción de cancer en los pacientes expuestos.

El presente trabajo forma parte de un proyecto de optimización de la protección radiológica en fluoroscopía, apoyado por la IAEA [12] aplicado en instituciones médicas de Rio de Janeiro, siendo uno de los objetivos la evaluación de dosis recibidas por pacientes en procedimientos fluoroscópicos realizados con y sin intensificador de imagen. Se presentan aqui algunos resultados parciales de esta investigación en un hospital.

2. Materiales y métodos

Los exámenes fueron realizados con un equipo (Philips Müller Technique) con 30 años de uso, generador trifásico Müller-Medio 50, pantalla intensificadora, tubo de raios X bajo la mesa,

diafragma regulable, focos fino y grueso de 1,2 e 2,0 mm, respectivamente, usandose normalmente el foco grueso. Todos los controles son manuales. Para escopía, la corriente puede variarse entre 0 y 6 mA y la tensión del tubo entre 40 y 110 kVp, y dispone de un indicador de tiempo de escopia con alarma sonora a los 5 minutos. El seriógrafo se acciona manualmente para obtener radiografías desplazando el chasis a una posición debajo de la pantalla, lo que acciona un disparador para exponer la película con la técnica radiográfica seleccionada. La película puede ser dividida para obtener dos imágenes radiográficas en la misma, desplazando manualmente una lámina de plomo debajo de la pantalla fluorescente, antes de la exposición. Existe una rejilla antidifusora sostenida por resortes para permitir su movimiento en el momento de la exposición.

Se utilizaron medidores Diamentor M4 y E (PTW, Freiburg, Alemania) para medir el producto dosis-área (DAP). La calibración de los instrumentos fue realizada *in situ*, considerando la atenuación de la mesa de exámen. El fabricante garantiza una incertidumbre de ±1% en la medida del DAP [13]. Se aplicó un único factor de calibración: el promedio de los obtenidos para los diferentes kVp utilizados, porque esto no introdujo errores significativos.

Se adquirieron datos en 23 exámenes de enema de bario con doble medio de contraste (clisteropaco), 13 seriografías gastroduodenales, 3 esofagografías y 13 histerosalpingografías, realizados según los protocolos médicos de la institución. Los exámenes fueron conducidos por médicos del primer año de la residencia en radiología. Los datos registrados en cada examen fueron: técnica fluoroscópica (kVp, mA), tiempo de exposición, técnica radiográfica (kVp, mAs), número total de imágenes, tamaño de campo fluoroscópico y radiográfico y DAP total. En los exámenes de enemas de bario y de histerosalpingografía fue posible registrar el DAP de la parte fluoroscópica y el DAP de la parte radiográfica del examen y estimar la dosis por imagen y la tasa de dosis en fluoroscopía.

3. Resultados y discusión

En las tablas I y II se presentan los resultados obtenidos en los exámenes evaluados. De la tabla I, es posible observar que los valores de DAP total resultaron extremamente elevados al compararlos con los niveles de referencia para fluoroscopía actualmente disponibles [4][5][14][15][16] (entre paréntesis y en negrito en la tabla I). La comparación directa de nuestros resultados con estos valores derivados de dosimetría en equipos con intensificador de imagen no es rigurosamente procedente pero sí válida a fin de tener una referencia en relación a los valores típicos actuales para los procedimientos evaluados.

En histerosalpingografías, Fernández et al [16] midieron en España valores de DAP total entre 2,5 y 16 Gycm^2, con una media de 7,5 imágenes y tiempos de exposición entre 0,1 e 1 minuto. Los DAPs totales (3er. cuartil) obtenidos en nuestro estudio fueron alrededor de 15 veces mayores, a pesar de que el número promedio de imágenes es el mismo. Esto evidencia, al igual que para enemas de bario, la contribución al DAP total de la parte fluoroscópica del examen, mostrada en la tabla II. Para seriografías, las medidas resultaron de 3 a 6 veces mayores que los valores de referencia, y para enemas de bario, superiores por un factor de 3 a 5. Estos hechos sugieren que los protocolos médicos sean revistos, además de evaluar el desempeño del equipo.

Algunos problemas detectados em relación a la ausencia total o parcial de procedimientos de optimización se deben, en general, a la falta de recursos financieros y otras dificultades (como la falta de físicos médicos y la escasa formación en protección radiológica de los radiólogos) que la mayoría de las instituciones de salud pública tienen que enfrentar en muchos países en desarrollo. Los exámenes tienen que ser realizados por los profesionales con los equipos y herramientas disponibles.

En los casos evaluados, las dosis/imagen fueron relativamente bajas, aunque no se evaluó la calidad de imagen (combinación película-pantalla verde). Las tasas de dosis son consideradas elevadas, en función de las recomendaciones actuales [11].

Tabla I Resultados de las medidas realizadas en la evaluación de procedimientos fluoroscópicos realizados con el equipo de rayos X sin intensificador de imagen. n: número de exámenes evaluados. Los valores de los niveles de referencia actualmente disponibles están indicados entre paréntesis y en negrito en la tercera columna.

	Tiempo [min]	N°. Imágenes	DAP total [Gycm^2]	Dosis por imagen [mGy]	Tasa de dosis escopía [mGy/min]
ENEMA DE BARIO (n = 23)			**(37-62)**		
Rango	3,8-21,7	5-14	85-316		50
Media	8,8	9,7	159	4	16
Desviación Estandar	4,2	1,8	63	4	56
3er Cuartil	11,2	10,0	190	1	
SERIOGRAFIA (n = 13)			**(25-53)**		
Rango	3,4-16,1	8-17	62-345		
Media	8,0	13,8	136		
Desviación Estandar	3,1	3,2	74		
3er Cuartil	9,3	17,0	164		
HISTEROSALPINGOGRAFIA (n = 13)					
Rango	1,2-7,2	5-10	25-118		
Media	3,9	7,3	107	3	24
Desviación Estandar	1,6	1,4	51	2	3
3er Cuartil	4,5	8,0	136	4	26
ESOFAGOGRAFIA (n = 3)			**(10)**		
Rango	3-7,3	6-10	40-106		
Media	5,1	8,7	105		
Desviación Estandar	2,2	2,3	44		

Tabla II Estimativas de las contribuciones radiográfica y fluoroscópica en exámenes de enema de bario e histerosalpingografía.

	Tiempo [min]	N°. Imág.	DAP total [Gycm^2]	DAP grafía [Gycm^2]	% Grafía	DAP escopía [Gycm^2]	% Escopía
ENEMA DE BARIO (n = 23)							
Rango	3,8-21,7	5-14	85-316	1073-3437	6-25	76-288	75-95
Media	8,8	9,7	159	2056	13	147	87
Desviación Estandar	4,2	1,8	63	717	6	67	6
3er Cuartil	11,2	10,0	190	2594	17	179	92
HISTEROSALPINGOGRAFIA (n = 13)							
Rango	1,2-7,2	5-10	25-118	504-1109	13,5-15,2	32-62	85-87
Media	3,9	7,3	107	807	14,4	47	86
Desviación Estandar	1,6	1,4	51	428	1,2	21	1
3er Cuartil	4,5	8,0	136	958	14,8	54	86

4. Conclusiones

Hoy en dia se dedica mucha atención a la dosimetría en equipos modernos y sofisticados, pero en algunos países, la población continúa siendo irradiada con equipos fluoroscópicos sin intensificador de imagen. Este trabajo pretende llamar la atención hacia la optimización de la protección radiológica en instalaciones que todavía usan equipos sin intensificadores. Aún cuando su uso esté "justificado" en ciertas situaciones, es posible aplicar medidas de protección radiológica a

pacientes que inevitablemente serán expuestos. Mientras estos equipos no puedan ser desactivados, debería incentivarse la dosimetría a pacientes, la aplicación de conductas de protección radiológica y de programas de garantía de calidad.

Estos resultados preliminares muestran que aún existen muchos problemas que deben ser resueltos en nuestro país. El hecho de disponer de valores numéricos para los parámetros evaluados constituye un paso importante que servirá para tomar acciones a ser implementadas en fluoroscopia. En Brasil estos equipos serán desactivados hasta 2003, las mejorías se hacen de forma gradual y las disposiciones legales ayudan a corregir los desvíos. Sin embargo, en otros países que no disponen de esta posibilidad, probablemente estos equipos seguirán siendo utilizados, con la consiguiente exposición a los pacientes.

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RADIOLOGICAL PROTECTION OF THE RADIOTHERAPY PATIENT?

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Abstract

We propose that the system and concepts of radiation protection should not be used with reference to radiotherapy patients. We justify this on conceptual grounds. The patient undergoing radiotherapy procedures, as prescribed by the medical practicioner, is protected by the quality assurance system legally required for medical exposures.

Introduction

The medical exposure of a patient for purposes of radiotherapy is unique in that radiation itself is the healing agent, applied at a dose rate and dose range over three orders of magnitude higher than that occurring naturally. Moreover, unlike at natural dose levels, much is known quantitatively about the dose-effect relationship, both for the curing effect and for the post-irradiation complications, which inevitably accompany radiotherapy. Figuratively speaking, radiation protection is concerned with avoiding the generation of cancer by avoiding exposure, while radiotherapy, in contrast, relies on delivering a dose as high as possible to eradicate the cancer which has already developed. Whether to apply principles of radiation protection to the radiotherapy patient, is a question worth considering. It is the topic of this Conference.
We propose that the system and concepts of radiation protection should not be used with reference to radiotherapy patients. We will justify our view on conceptual grounds, in the context of relevant regulations and recommendations.

Radiotherapy

Radiotherapy, for curative or palliative intent, is a well-described sequence of procedures [1-3], the general aim of which is to achieve cytotoxic levels of irradiation to well-defined target volumes of the patient, while as far as possible sparing the exposure of surrounding healthy tissues. Radiotherapy seeks to provide an optimal uniform distribution of dose to the target volume relative to normal tissue, the point of optimisation being to deliver a dose as *high* as

possible within the available "therapeutic window". This "window" arises as a range of dose applied to the target volume where the probability of cure exceeds the probability of complications, both probabilities increasing with dose (up to saturation) in a non-linear manner. According to present radiobiological models, the dose-effect relationships used to describe the probability of cure and the probability of complications are mathematical expressions involving exponential or power dependence on dose [4]. A total dose of the order of 60 Gy, or so, to the target volume, delivered in up to about 30 daily fractions of about 2 Gy, is typically applied. It is well recognised that the biological effect is not additive with dose, and depends on the radiosensitivity of the tissue and on the timing of the fractionation scheme. Through careful planning and beam shaping techniques (most frequently, external beams of megavoltage photons and electrons, gamma-rays from sealed sources placed internally, or beta- or gamma- rays from radiopharmacological agents, are used) the dose to the target volume is maximised while sparing the neighbouring healthy tissue or so-called critical volumes. Modern radiotherapy is a complex procedure involving advanced technology and close co-operation between qualified specialists trained in the areas of medicine, radiation physics and technology. A detailed quality assurance system in radiotherapy is presently required by national and international recommendations [5].

Conceptual

Clearly, the governing principles of radiation protection: justification of a practice, dose limitation and optimisation of protection and safety, as stated in the Basic Safety Standards [5], do not apply in the case of radiotherapy. In this context, one may also take issue with the statement concerning the control of medical exposures in the 1990 ICRP Recommendations (S36, p. 74): "*...If the practice is justified and the protection optimised, the dose in the patient will be as low as is compatible with the medical purposes.*" Indeed, radiotherapists insist on delivering a dose to the tumour *as high* as is compatible with the probability of occurrence of complications. Radiotherapy is unique in this aspect, unlike, e.g., medical diagnostics. The dose to which the tissue surrounding the target volume is exposed to, as well as the limits of dose applied to critical targets, are governed strictly by medical and *not* by radiation protection considerations. Healthy neighbouring tissues are likely to acquire doses well above levels considered to be of relevance to radiation protection. Disregarding the dispute as to the linearity of dose-effect relationships at low doses, there is unanimous acceptance of the non-

linearity of this relationship at dose levels used in radiotherapy. Application of multiplicative dose factors such as those used in defining equivalent dose or effective dose [5,6] is thus inappropriate, even if values of these factors were known at such high dose levels. Therefore, the usage of the Sievert as unit of effective dose equivalent or effective dose, and of collective dose (in units of man Sv), cannot be justified in the case of radiotherapy.

Discussion

A case in point is the study of Beentjes [7], quoted in Annex C of UNSCEAR 1993 Report [8]. Here, the collective effective dose from radiotherapy in the Netherlands for 1971 (male and female) radiotherapy patients has been calculated at 18630 man Sv, yielding an average of 9.67 Sv per patient (!). Additional calculations were made using cancer fatality coefficients taken from ICRP-60 [6], presumably valid at low-dose, or the "stochastic" level of radiation hazard. It is difficult to imagine how could meaningful evaluations be made over a wide range of doses, presumably from 60 Gy in the target area to a value orders of magnitude smaller, from scattered radiation, considering, e.g. exponential dose-effect relationships known to be valid at the higher dose levels. The meaning of the collective effective dose, let alone the Sv under such non-uniform irradiation conditions and at such high doses is difficult to understand. In our view, this example illustrates the futility of applying concepts and units of radiation protection in radiotherapy.

Quality assurance in radiotherapy

The quality assurance systems in radiotherapy, presently recommended at national and international levels [5], usually pertain to the complete procedure, including calibration of sources, clinical dosimetry, computerised radiotherapy planning systems and recording and reporting all the procedures [9]. Detailed quality assurance tests have been implemented for all radiotherapy equipment, by national and international authorities. It is through strict adherence to such quality assurance systems that patient safety is assured and the possibility of, e.g., accidental overexposure of the patient avoided. Possible stray or scattered radiation related to radiotherapy is of no consequence to the patient's radiation protection, as it is

usually a contribution several orders of magnitude smaller than that relevant to the curative does applied. Thus, in our view, the ultimate safety of the radiotherapy patient results from the correct procedure of applying the medical exposure within the appropriate quality assurance system, and not from protecting him against exposure to radiation. Information, such as that provided in the last UNSCEAR report [10] on, e.g., total dose applied to target volumes in a given number of patients for given types of malignancies is of interest to the specialist but no information concerning population exposure patterns can, or should be derived from such data. Whether any dose-response relationships over a wider range of doses could be extracted from this data in conjunction with additional information on the generation of secondary radiogenic cancers in radiotherapy patients, is a matter for further consideration.

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PROTECTIVE EFFECTS OF SEVERAL PLANT POLYPHENOLS AGAINST CHROMOSOMAL DAMAGE INDUCED IN VIVO BY X-RAYS. COMPARATIVE STUDY VERSUS DIOSMIN AND RUTIN

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ABSTRACT

Protective effects of grape (Vitis *vinifera*) seed (GSE), *Citrus spp.* fruits (CE) and olive (*Olea europaea* L.) leaf (OL) extracts, the flavonoids diosmin and rutin, widely used as pharmaceuticals, and dimethylsulphoxide (DMSO) against chromosomal damage induced by X-rays were determined by using the micronucleus test for anticlastogenic activity. The reduction of the frequency of micronucleated polychromatic erythrocytes (MnPCEs) in bone marrow of mouse exposed to X-rays was examined. The most effective compounds were, in order: GSE ≈ CE > rutin ≈ DMSO ≈ OL > diosmin. These results suggest a correlation between the antioxidant and anticlastogenic activity of these polyphenolic extracts.

INTRODUCTION

The micronucleus test "in vivo" is a method devised primarily for screening chemicals for chromosome-breaking effects. The test substances are normally applied sub-acutely to small mammals, and the effect is read in direct smears from bone marrow. The micronucleus assay on mouse bone marrow polychromatic erythrocytes, originally developed by Schmidt (1975) [1], is probably the most frequently used in vivo short-term genotoxicity tests. Bone marrow micronucleated erythrocytes provide a simple and rapid method for detection of chromosomal damage by chemical and physical agents [1-4]. For this reason, micronuclei have been widely used to detect chromosomal breakage and chromosome lagging "in vivo" and "in vitro" [2-4].

MATERIALS AND METHODS

Plant Materia: Grape Seeds Extract (GSE) was obtained from four different varieties of *V. vinifera* grapes selected in different areas of the community of Murcia (Spain): "Macabeo" and "Airen" are white grapes and "Tempranillo" and "Monastrel" are red grapes. The grapes were picked at their optimum commercial maturity.

Citrus Fruit Extract (CE) was obtained from immature fruits of several characteristic cultivars from the region of Murcia from three *Citrus* species: *Citrus limonia, Citrus paradisi* and *Citrus aurantium*. The fruits were harvested from the trees by natural abscission during the initial phase of the fruit growth.

Olive Leaf Extract (OL) was obtained from *Olea europaea* L. leaves of five cultivars: Villalonga, Alfafarenca, Picual, Cornicabra and Blanqueta from the regions of Andalucia and Murcia. The leaves were collected when the olive fruits were picked at their usual commercial time.

Chemical Reagents:

Diosmin and rutin were obtained from Extrasynthèse S.A. (Genay, France). DMSO was obtained from Merck (Darmstadt, Germany). Fetal calf serum was obtained from Sigma Chemical Co. (Madrid, Spain).

Extraction and HPLC Analysis of Polyphenolic Compounds from Plant Material

The methods to obtain and quantify the grape seed (GSE), citrus (CE) and olive leaf (OL) extracts have been described previously.

Animals

Adult male Swiss albino mice, 9-12 weeks of age, weighing approximately 25 g were used from our animal colony (license 300030-2A). All mice were acclimatized for at least one week prior to dosing. They were maintained under constant environmental conditions with 12/12 h light/dark cycle. They were fed standard granulated chow (Rodent toxicology diet®, BYK Universal Beekay Feeds, France) and given drinking water ad libitum. Each group consisted of 6 mice.

Chemicals and Treatment

The polyphenolic extracts were administered orally. All solutions were freshly prepared immediately before treatment of the animals. GSE, CE, and OL were dissolved in 0.2 % drinking water and administered during 5 days before the X-irradiation. DMSO was dissolved in water (50 g/100 ml). Diosmin and rutin were dissolved in DMSO (300 mg/ml). DMSO, diosmin and rutin were injected in a single dose of 0.6 ml directly into the gastric lumen 6 h before the X-irradiation.

Exposure to X-rays

The mice were whole-body X-irradiated using CGR apparatus with radioscopy (General Electric, Spain). During exposure to X-rays, the animals were placed in a well-ventilated acrylic box. Irradiation conditions: 120 kV, 1.4 mA, filter 2.5 mm Al, exposure rate of 2cGy/min, FDO 100 cm. The mice were exposed to a single dose of 48 cGy. The X-ray exposure was established by means of thermoluminescent dosimeters (TLDs) (GR-200®, Conqueror Electronics Technology Co. Ltd, China). The TLDs were supplied and measured by CIEMAT (Ministry of Industry and Energy, Spain)

Bone Marrow Preparation and Staining

Two femurs were removed from each mouse 24 h after X-irradiation, and bone marrow samples were taken. The bone marrow cells were dispersed by gently pipetting and then collected by centrifugation at 1,000 rpm for 5 min at 4°C. Cell pellet was resuspended in one drop of fetal calf serum and bone marrow smears (two slides per mouse) were prepared. The slides were coded to avoid observation bias. After 24 h air-drying, the smears were stained with May-Grünwald / Giemsa[48, 49]. With this method polychromatic erythrocytes (PCEs) stain reddish-blue and normochromatic erythrocytes (NCEs) stain orangey, while nuclear material is a dark purple colour. The number of micronucleated polychromatic erythrocytes (MnPCEs) among 2,000 PCEs per mouse (1,000 PCEs per slide) was determined. The slides were examined at 1,000x magnification using a Zeiss light microscope (Oberkochen, Germany).

Statistical Evaluation

Differences in the frequency per animal of MnPCEs per 1,000 PCEs were tested by analysis of variance and evaluated using Student's t-test.

RESULTS

The data presented (Figure 1) show that whole-body exposure to 48 cGy of X-rays results in a substantial increase in the frequency of MnPCEs in comparison with that occurring spontaneously ($p<0.001$). There is a significant reduction of frequency of MnPCEs in all pre-treated, irradiated groups compared with the control and irradiated group.

Figure 1 shows the influence of treatments on the frequencies of MnPCEs in the bone marrow of animals non-irradiated and irradiated, permitting thus to compare the potential toxicity of each treatment vs. their anticlastogenic activity. Diosmin, rutin, GSE, CE and OL show very low levels of MnPCEs generation, similar in respect to non-irradiated control data,

while the sulphur-containing compound, DMSO, presents higher genotoxicity levels (> 5 MNPCEs/ 1000 PCEs) than the other compounds studied. Also, Figure 1 shows the influence of X-irradiation on the frequencies of MnPCEs in mouse bone marrow. There is a significant reduction of frequency of MnPCEs in the pre-treated groups compared with the irradiated control group. The order of treatments with respect to the minor level of MnPCEs generated after irradiation is: GSE ≈ CE < rutin ≈ DMSO ≈ OL < diosmin (at least $p<0.05$ in each one of the steps represented).

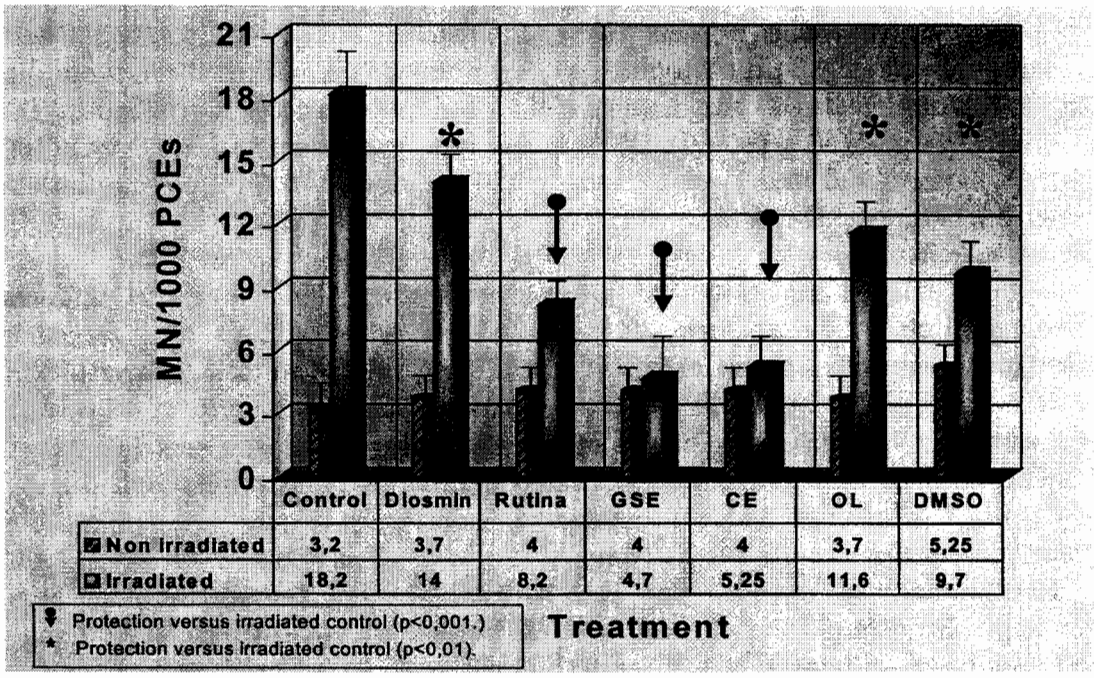
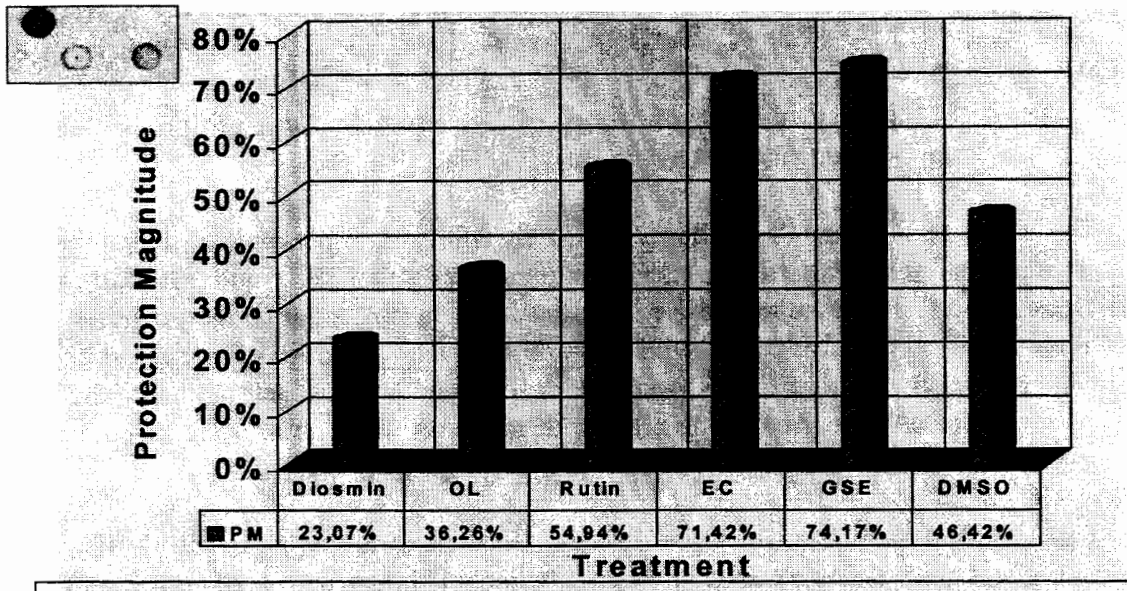


Figure 1. Influence of treatments and X-rays irradiation on the frequencies of MnPCEs in mouse bone marrow (irradiated and non-irradiated)

The radioprotective effects, and consequently the anticlastogenic activity of the different treatments used, were established according to the increase in the MnPCE level in animals after irradiation and their relation with this level in control animals, obtaining a percentage value that shows the level of protection of each treatment. Figure 2 shows the values of these protection capacities, the GSE-pre-treated group being the most effective protection against in vivo chromosomal damage and cytotoxicity induced by X-rays. The order of effectiveness was: GSE ≈ CE > rutin ≈ DMSO ≈ OL > diosmin.



Magnitude of protection (%) = $((F_{control} - F_{treated}) / F_{control}) \times 100$.
Where $F_{control}$ = frequency of MnPCEs in irradiated animals.
$F_{treated}$ = frequency of MnPCEs in animals treated before the X-ray irradiation (diosmin, rutin, GSE, CE and OL)[69].

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Pepsi Radiology 98

DECREASE OF THE THYROID PEROXIDASE ACTIVITY INDUCED BY X RAYS.

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ABSTRACT

The effect of different X-ray doses (0-20 Gy) on thyroid peroxidase activity in three groups of rabbits: normofunctioning, propylthiouracil-treated (PTU) and protirelin-treated (TRH) is described. The results show a significant decrease in peroxidase activity in the normofunctioning animals irradiated with a single or fractioned dose of X-rays. The PTU-treated animals show no significant modification of their enzyme activity, and the TRH-treated animals present the greatest sensitivity to radiation of all groups, in relation to the radioresponse of the peroxidase activity studied.

INTRODUCTION

Some studies show that the thyroid function decreases following external radiation of the thyroid gland with doses as used on human patients [1], and with a fractioning of doses similar in experimental studies [2]. It has been suggested that this functional decrease is due to immediate cellular death and lesion of the enzyme systems of the radiation-induced surviving cells [1]. However, there are very few studies on the effect of radiation on the enzyme systems of the follicular cells.

In vitro studies suggest that the protein synthesis and the different cellular enzymatic systems have a different sensitivity, although they are only affected by high doses of external radiation (500-1000 Gy or more) [3]. In contrast, it has been reported that the synthesis of purines may be modified after external radiation of only a few hundred rads [1].

Studies with 125-I confirm this different sensitivity of the enzyme systems and suggest that irradiation would cause changes in the enzymatic systems of the follicular cells [4,5].

This paper presents the results of a study on thyroid peroxidase activity in rabbit thyroid glands irradiated with different X-ray doses, and discusses the significance of the findings.

MATERIALS AND METHODS

ANIMALS

Sixty specimens of 3-month-old New Zealand rabbits (Biocenter, Spain), weighing approximately 2,700 g at the beginning of the study and kept at 18-22 °C, an ambient humidity between 50-70% and in a 12-h day-night cycle, were fed with commercial fodder (U.A.R. 112 Panlab., Spain) and allowed water ad libitum. The animals were divided into three groups:

- Group I: Nine animals which had received no type of treatment prior to irradiation (normofunctioning group).
- Group II: Nine animals whose thyroid functional activity was reduced by administration of 6n-propyl-2-thiouracil (PTU) (Sigma, USA) over the 4 weeks prior to irradiation. The PTU was administered to the drinking water at a concentration of 0.2% and supplemented with 1% sucrose.
- Group III: Nine animals whose thyroid functional activity was stimulated by administration of protirelin (TRH) (Lab. Frumtost-Prem, Spain) during the week prior to irradiation. The TRH was administered intravenously, at a doses of 200 μg/8 hours, through a polyethylene catheter inserted into the right external jugular vein.

A fourth group of 33 animals, denominated the variable post-irradiation period group, was used to plot a radioresponse curve of thyroid peroxidase activity (TPO) at 0, 24 and 48 hours after irradiation.

IRRADIATION

The irradiation field was 5 cm in diameter upon the thyroid cartilage. The X-rays were delivered by a therapy unit (Securix 2612 Compact, CGR) with 120 kV, 12 mA, 1 mm Cu of HVL, filtration of 1 mm Cu and 0.5 mm Al, FSD 50 cm and absorbed dose rate of 1.15 Gy/min. In the first three groups, the total X-ray dose administered was O (as control), 10 Gy and 20 Gy, fractioned at 2 Gy/day, on alternative days. In the fourth group, the doses administered were 0,2,4,6,8,10,12,14,16,18 and 20 Gy, in a single session. A11 the animals were immobilised and conscious during irradiation.

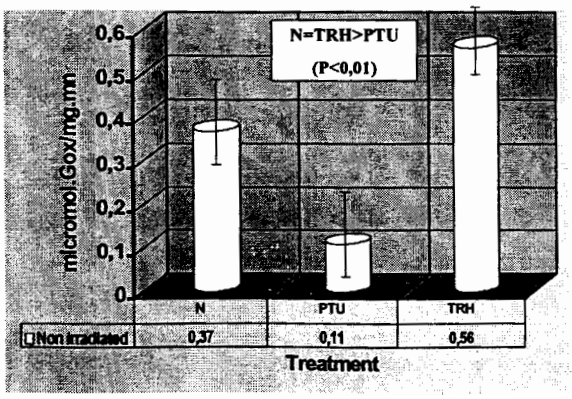
In the first three groups, the animals were slaughtered 24 hours after irradiation by traumatic decerebration, and their thyroid glands were subsequently removed. In the variable post-irradiation period group, the animals were slaughtered 0, 24 and 48 hours after irradiation.

PREPARATION OF THYROID PEROXIDASE (TPO): After thawing, the thyroid glands were weighed and divided into small pieces which were homogenized in a 100 mM carbonate buffer pH 10.2, containing 0.1 mM KI to stabilize the enzyme. The ratio of weight to volume of homogenisation was 1:5 (g:ml). The homogenate was fractionated by centrifugation to obtain the post-nuclear fraction at 700 g during 10 min. This fraction was treated with 1% Triton X-100 for 2 h at 4 °C to solubilize the enzyme from the membrane fraction. Finally, the preparation was ultracentrifuged at 105.000 g for 1 h and the supernatant was used for TPO activity determination.

ASSAY FOR PEROXIDASE ACTIVITY: The peroxidase activity of the thyroid preparations was tested with guaiacol method as described by Chance and Maehly [6], slightly modified by Solano [7]. Briefly, the method consists on measuring the absorbance increase per minute, at 470 nm using a spectrophotometer and cuvettes of 1 ml total volume. The reaction mixture contained 0.9 ml of 20 mM guaiacol in 50 mM Tris-HCl buffer, pH 8.2, 50 µl of 50 µl of rabbit thyroid extracts. The activity units was defined as the amount of enzyme that produced an increase of an absorbance unit per minute under the assay conditions. PROTEIN DETERMINATION: The protein content of the enzymatic extracts was determined by a modified Lowry method [9] using BSA as standard. The statistical treatment consisted of equality contrasts of the means and correlation. Values of less than 0.05 ($p<0.05$) were considered significant.

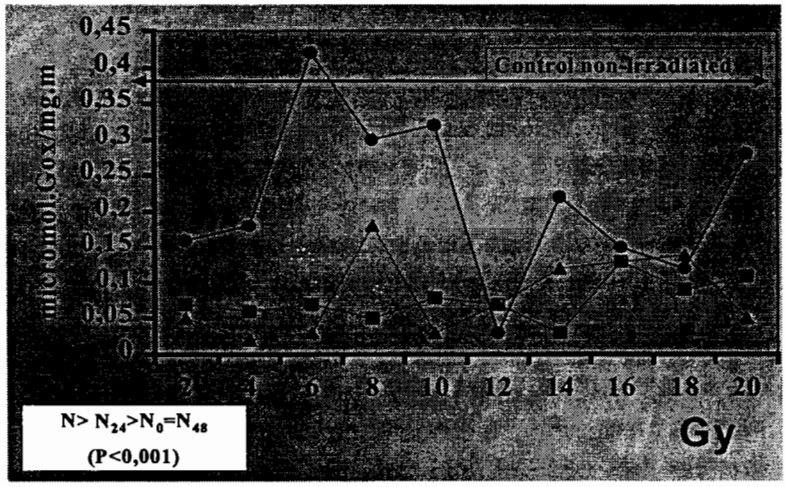
RESULTS.

Non-irradiated animals: The values for TPO activity in the non-irradiated animals are

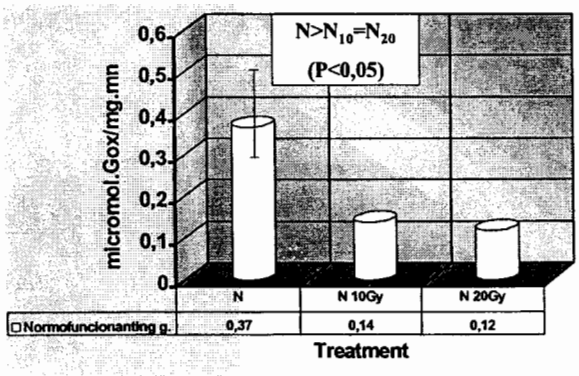


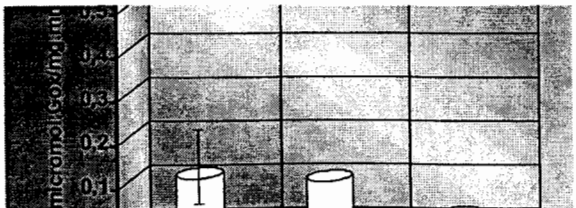
shown in Figure 1. The increase in TPO activity in TRH-treated animals was 48 % compared to the non-irradiated normofunctioning animals. The drop in activity in the PTU-treated animals was 72 compared to the values presented by the normofunctioning animals. However, the present data only demonstrate significance in the fall in the TPO activity of the PTU-treated animals when compared to the other two groups; the values of the latter two groups are similar. This relation may be expressed as follows: N=TRH>PTU ($p<0.01$).

Normofunctioning variable post-irradiation period group : the values for TPO activity in the variable post-irradiation period group are shown in Figure 2. The irradiated animals presented a decrease in TPO activity, even with the lowest radiation doses (2 Gy), in the three study periods (0, 24 and 48 hours). Analysis of the statistical significance reveals that TPO activity in the irradiated animals with a post-irradiation period of 24 hours is greater than TPO activity in the irradiated animals with a post-irradiation period of 0 and 48 hours; the activities of the latter two groups (0 and 48 hours) are similar. This relation may be expressed as follows: $N>N_{24}>N_0=N_{48}$ ($p<0.001$).



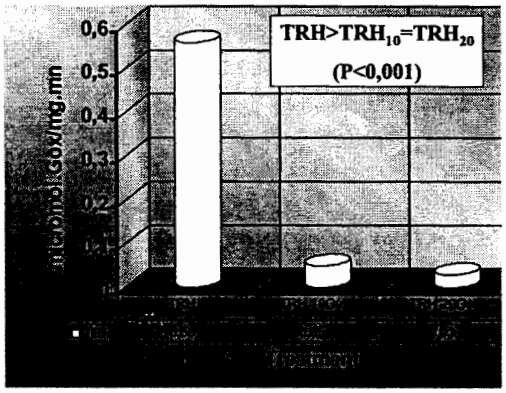
Groups irradiated with a fractioned dose and experimental modification of the thyroid function: The values for TPO activity in these animals are shown in Figure 3. The normofunctioning animals irradiated with 10 and 20 Gy (2 Gy/alternative days) show a sharp





decrease in TPO activity compared to that presented by the non-irradiated normofunctioning animals. This relation shows statistical significance and can be expressed as follows: $N_0>N_{10}=N_{20}$ ($p<0.05$).

The PTU-treated animals irradiated with 10 and 20 Gy show no significant differences in TPO activity from that presented by the non-irradiated PTU-treated animals: $PTU_0=PTU_{10}=PTU_{20}$.



The irradiated TRH-treated animals present a drastic fall in the TPO activity of their thyroid glands compared with the values of the non-irradiated TRH-treated animals: $TRH_0>TRH_{10}=TRH_{20}$ ($p<0.001$). In the three animal groups (normofunctioning, PTU-treated and TRH-treated), irradiation with 20 Gy shows a greater decrease in TPO activity than 10 Gy; however, these differences are not statistically significant.

CONCLUSION

This work show that the peroxidase activity of the follicular cells decrease following external radiation of the thyroid gland with a fractioning of doses similar to that used in human oncology.

The animals used in this study were treated according to the Biological Council Guidelines on the Use of Living Animals in Scientific Investigations (2nd ed.).

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DRUG INTERACTION WITH RADIOPHARMACEUTICALS AND THE IMPORTANCE FOR THE RADIATION DOSE TO THE PATIENT

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ABSTRACT

A central aspect of the profession of health physics is to establish practical scientifically based radiation protection standards with the worthy aim of minimizing the detriment while at the same time enhancing the benefits derived from sources of ionizing radiation. The biodistribution or pharmacokinetics of radiopharmaceuticals may be altered by drugs and it can lead to misdiagnosis or the necessity to repeat the examination, increasing the dose to the patient. Vincristine (0.03mg/ml) was administered into female mice. One hour after the last dose, ^{99m}Tc-GHA (7.4 MBq) was administered and the animals (n=15) were sacrificed. The organs were isolated and the percentages of radioactivity (%ATI/g) in the organs were calculated. We calculated the Drug Interaction Factor (DIF) and the Effect Mass Factor (EMF). The results were statiscally significant (Wilcoxon test, $p<0.05$) and have shown that the DIF to ^{99m}Tc-GHA was to thymus 1.70, to pancreas 1.68, to uterus 0.42, to spleen 0.78, to lymph node inguinal 0.55, to kidney 0.45, to heart 0.59. The EMF was to ovary 0.28, to uterus 0.64, to thymus 0.17, to spleen 0.45, to lymph node inguinal 0.24, to kidney 0.80, to liver 0.77, to pancreas 0.61. The effects could be explained by the metabolization and/or therapeutic action of these drug.

INTRODUCTION

The earliest considerations of radiation effects and protection were built on the principles that a certain specific level of radiation can be incurred by various tissues without apparent ill effect. This in turn logically led to concept of a tolerance dose. More completely and precisely, the tolerance dose was considered to be that level of radiation to which an individual could be continuously exposed without demonstrable ill effect [1].

Hence, drug-radiopharmaceutical interaction will be defined as altered biologic behavior due to tissue response of administered drug. When the modified biologic behavior is desired, the alteration is used for diagnostic intervention or drug therapy monitoring; when it is undesired; it may be due to toxicity or direct interaction. If unknown, the drug interaction with radiopharmaceuticals can lead to misdiagnosis or the necessity to repeat the examination, increasing the dose to the patient [2, 3, 4].

More than 80% of all imaging studies (mostly anatomic) currently use technetium-99m (^{99m}Tc), because it has turned out to be the ideal isotope from various considerations[2, 3, 5, 6]. The biological activities of vincristine can be explained by its ability to bind specifically to tubulin and to block the capability of the protein to polymerize into microtubules [7]. The radiopharmaceutical 99mTc-GHA (glucoheptonic acid) is used to renal study [8].

In this paper we are evaluated the effect of vincristine on the biodistribution of the radiopharmaceutical 99mTc-GHA.

MATERIAL AND METHODS

Vincristine (Oncovin, Eli Lilly, Brazil LTDA) (0.03 mg, 0.3ml) was administered by ocular plexus via into female isogenic Balb/c mice (n=15), in three doses with a total interval of 96 hours. After 96 hours, the animals were sacrificed, the various organs pancreas, lymph nodes (inguinal and mesentheric), thyroid, brain, thymus, ovary, uterus, spleen, kidney, heart, stomach, lung, liver and

bone were isolated and their mass determined in an analytical balance. The mass of the organs of these animals were compared with the control group, without vincristine. The statistical analysis of the results were performed with Wilcoxon test, $p< 0.05$. To study the vincristine effect in the biodistribution of the radiopharmaceutical, one hour after the last dose, 0.3 ml of ^{99m}Tc-GHA (7.4 MBq) was injected by the same via. In the control group (n=15), vincristine was not administered. To prepare the GHA, ^{99m}Tc, as sodium pertechnetate, recently milked from a ^{99}Mo/^{99m}Tc generator (Instituto de Pesquisas Energéticas e Nucleares, Brazil) was added to a kit of DMSA (Laboratório de Radiofarmácia, INCa, Brazil). The radiochemical control was performed by ascendent chromatography, using paper Whatman nº 1 and 0.9% NaCl solution and acetone as mobile phases. The labeling efficiency was > 95% and the percentage of free pertechnetate was < 5%. After 0.5 hour the animals were rapidly sacrificed. The various organs were isolated pancreas, thyroid, brain, thymus, ovary, uterus, spleen, kidney, heart, stomach, lung, liver, bone and lymph nodes (inguinal and mesentheric) and the radioactivity of the ^{99m}Tc-DMSA and ^{99m}Tc-GHA were counted in a well counter NaI(Tl) (Automatic Gamma Counter, 1272 Clinigamma, LKB, Wallac, Finland). The percentages of radioactivity per gram of tissue (% ATI/g) in the organs were calculated dividing the total activity in each organ by the mass of each organ. The percentage of radioactivity in each organ was compared with the control group. Statistical analysis were performed by Wilcoxon test ($p<0.05$). After that, we have calculated the a Drug Interaction Factor (DIF), dividing the %ATI/g in the organs of the treated animals by the %ATI/g in the organs of the control animals and the and the Effect Mass Factor (EMF), dividing the mass of the organs of the treated animals by the mass of the organs of the control animals.

RESULTS

Table 1 shows the relationship between the mass of the isolated organs of the group of mice that was treated with vincristine and the control group (no treated) and the values of the EMF. The analysis of the results in table 1 shows no significant alteration of the mass of lung, stomach, heart, bone, thyroid and brain and reveals significant ($p<0.05$) decreasing of the mass of spleen, thymus, kidneys, liver, ovary, pancreas, lymph nodes (inguinal and mesentheric) and uterus.

Table 1 - Effect of vincristine on the mass of different organs from female mice

	mass (g)		EMF
Tissue	control	treated	
Lung	0.1446 ± 0.0131	0.1482 ± 0.0167	1.02
Stomach	0.1187 ± 0.0131	0.1223 ± 0.0101	1.03
Heart	0.0858 ± 0.0093	0.0855 ± 0.0119	0.99
Thyroid	0.0135 ± 0.0035	0.0121 ± 0.0035	0.89
Bone	0.0387 ± 0.0082	0.0421 ± 0.0065	1.08
Brain	0.3831± 0.0293	0.3799 ± 0.0162	0.99
Spleen	0.0662 ± 0.0088	0.0300 ± 0.0059	0.45
Thymus	0.0280 ± 0.0055	0.0050 ± 0.0014	0.17
Kidneys	0.1207 ± 0.0122	0.0974 ± 0.0116	0.80
Liver	0.9734 ± 0.0597	0.7545 ± 0.0933	0.77
Ovary	0.0330 ± 0.0087	0.0095 ± 0.0027	0.28
Pancreas	0.0152 ± 0.0022	0.0094 ± 0.0019	0.61
Uterus	0.0453 ± 0.0097	0.0292 ± 0.0069	0.64
Lymph node inguinal	0.0328 ± 0.0062	0.0081 ± 0.0020	0.24
Lymph node mesentheric	0.0312 ± 0.0077	0.0079 ± 0.0023	0.25

Vincristine was administered into female mice Balb/c (n=15). The animals were sacrificed, the organs isolated and their mass determined. The results were compared with the control group, without vincristine, and statistical analysis were performed (Wilcoxon test, $p< 0.05$). EMF is the effect mass factor.

Table 2 shows the uptake (%ATI/g) of ^{99m}Tc-GHA in the group of the mice that was treated with vincristine and in the control group. The analysis of the results reveals an increase of the uptake in thymus and pancreas, and decreased the uptake in uterus, spleen, lymph nodes (inguinal and mesentheric), kidney and heart. The analysis of the results reveals no significant reduction of the uptake in lung, liver, ovary, stomach, thyroid, brain and bone and shows results of the DIF.

Table 2 - Effect of vincristine on the biodistribution of ^{99m}Tc-GHA in mice.

	%ATI/g		DIF
Organs	Control	Treated	
Uterus	2.0455 ± 0.1065	0.8692 ± 0.1387	0.42
Ovary	0.9120 ± 0.0802	1.1052 ± 0.1456	1.21
Spleen	0.9999 ± 0.1749	0.7838 ± 0.0815	0.78
Thymus	1.3154 ± 0.3192	2.2366 ± 0.3924	1.70
Lymph node inguinal	6.2145 ± 0.3363	3.4240 ± 0.7052	0.55
Lymph node mesentheric	2.6655 ± 0.1809	1.3971 ± 0.0799	0.52
Kidney	28.4313 ± 2.5731	12.9191 ± 2.6499	0.45
Lung	2.5168 ± 0.0976	2.3914 ± 0.1338	0.95
Liver	0.5023 ± 0.0376	0.6280 ± 0.0712	1.25
Pancreas	1.1370 ± 0.1535	1.9138 ± 0.3079	1.68
Heart	1.2822 ± 0.0827	0.7666 ± 0.1609	0.59
Thyroid	3.8910 ± 0.7460	4.0743 ± 0.7240	1.04
Brain	0.1261 ± 0.0347	0.1169 ± 0.0101	0.92
Bone	0.8991 ± 0.0860	0.8079 ± 0.0689	0.89
Stomach	3.6938 ± 0.4021	3.5615 ± 0.4080	0.96

Vincristine was administered into mice and after 96h ^{99m}Tc-GHA was injected. The animals, the were sacrificed organs isolated and the activities (%ATI/g) determined. The values are averages (n=15), Wilcoxon test, $p<0.05$. DIF is the drug interaction factor.

DISCUSSION

There is considerable evidence that the pharmacokinetics of radiopharmaceuticals may be altered by a variety of drugs, disease states and surgical procedures. If unknown, such factor may lead to poor organ visualization, a requirement to repeat the procedure resulting in unnecessary irradiation of organs of even misdiagnosis [2, 3, 5, 6]. The capability of determined protocols with vincristine to induce long term toxicities, as infertility in males of all ages [7, 9, 10], could also associated with the effect in uterus in our studies to the radiopharmaceutical. As vincristine is a immunosupressive drug [7], this effect could explain the alteration of the mass of the thymus, spleen and lymph nodes (inguinal and mesentheric), and could explain the alterations in these organs to %ATI/g of the ^{99m}Tc-GHA. This drug can produce hyponatraemia with abnormal water retention due to the non-osmotic rellease of anti-diuretic hormone [7]. This could explain the alterations in uptake in the kidney to the ^{99m}Tc-GHA. Mattos 1999, related the alteration in uptake of ^{99m}Tc-MDP in this organ.

In conclusion, in general, the results could be explained by a direct toxic effect in specific organs, the metabolization and/or therapeutic and immunosupressive action of vincristine. As vincristine is capable to alter, in mice, the mass of many organs, studies are now in progress to evaluate the anatomical characteristics of organs of patients that will be submitted to a protocol with vincristine. Moreover, the fact of the drug interaction can alter the uptake of the radiopharmaceutical in a specific target (organ), unexpected radiation dose in non-target organs is undesired. This is more relevant when this unexpected uptake is in a reproductive organ. Then, we suggest to consider, with special attention, the phenomenon of the drug interaction with the radiopoharmaceutical in the calculation of the radiation dose in organs.

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EVALUATION OF THE DOSIMETRIC PERFORMANCE CHARACTERISTIC OF FLUOROSCOPY SYSTEM USED IN MEDICINE

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Abstract

Objective To discuss establishment of diagnostic reference dose value in fluoroscopic examinations, for survey of 16 different types of fluoroscopy systems.

Methods Choosing dosimetric characteristic parameters including: IIESDR, ESDR(typical value) and ESDRmax (ESDR maximum), DAP which was calibrated in situ on the X-ray unit.

Results Results of dose survey are summarized in three tables, from these we could get wide changes in accordance with those in many other countries were resulting from maximum and minimum of IIESDR, ESDR and ESDRmax when measurements were performed at same entrance field size on I.I. Image Intensifier of the 15 fluoroscopy systems and under conditions of ABC. And also we could get less changes of DAP mean values, though differences for patient weight, technological parameters of fluoroscopic exam setting, fluoroscopic time and number of film were more remarkable.

Conclusions Measurements on IIESDR, ESDR(typical value) and ESDRmax (ESDR maximum) are not satisfied as diagnostic reference level. But it is suggested that DAP values, in fluoroscopic exam, are used as a tool to achieve this.

Introduction

Recently, medical diagnostic X-ray fluoroscopy systems with Image Intensifier (I.I.) have been used extensively in complex X-ray examination. They have occupied 25-40% of all the diagnostic X-ray exams for collective effective dose, which cause people's attention. This paper discusses the establishment of diagnostic reference dose value in fluoroscopic exams by dosimetric characteristic measurements for 16 different types of fluoroscopy systems.[1] [2] [3]

Material and Methods

16 types of fluoroscopy systems from 4 hospitals, three dosimetric characteristic parameters were chosen: (1) Entrance Surface Dose Rate of Image Intensifier (IIESDR), (2) Entrance Surface Dose Rate of phantom (typical ESDR and maximum $ESDR_{max}$), (3) Dose Area Product (DAP) in upper gastrointestinal(GI) Barium meal exam of patient.

The measure equipment often used includes: (1) a DIADOS dosemeter of PTW made in Germany, (2) a Solidose 400 dosemeter of RTI made in Sweden, (3) a DOSEGUARD-100 dose area product dosemeter of RTI made in Sweden. Moreover, using two pieces of 20mmAl plates and a piece of 2mmPb plate simulated typical adult patient and a fat adult patient. The three dosemeter were calibrated by the Secondary Standard Dosimetry Laboratory (SSDL) of LIH.

For twenty patients of Barium meal exam four fluoroscopy systems which were undertable were chosen, each patient (male or female) weight was 60 +/- 10kg . The DAP meter was calibrated in situ on X-ray unit to which was attached, then put the Solidose 400 dosemeter on 10cm¡Á10cm field and measured dose, put the film in a magazine with screen to measure the true size of exposure field, made the product of acquired dose and true area of exposure field calibrate to reading of DAP meter, and got a calibrating factor of DAP meter in situ for every fluoroscopy system, then we could calculate each patient DAP value($Gycm^2$) and DAP mean values of five patients in Barium meal exam for every fluoroscopy system.

Results

Table I gives main characteristics of 16 fluoroscopy systems. Table II gives dosimetric performance characteristic of IIESDR, ESDR and $ESDR_{max}$ for 16 fluoroscopy systems. Table III gives DAP measurements of twenty upper GI Barium meal exam for 4 fluoroscopy systems.

Table I Characteristics of 16 fluoroscopy systems investigated in several hospitals

Hospitals/Room Number	X-ray System				
	Type	Total filtration mmAl	Focus spot size mm	Size of II cm	Using Time of I.I. year
A/1	RCT	-	0.6 0.2	23 30	6
A/2	RCT	-	-	23	14
A/3	RCT	-	-	23	4
A/4	C-arm	-	-	13 17 30	3
A/5	RCT	-	0.6 0.2	23	8
A/6	RCT	-	0.6 0.2	23	4
A/7	RCT	5.2	-	23	13
B/1	RCT	4.8	0.6 0.2	23	7
B/2	RCT	-	-	23 30	2
B/3	C-arm	-	-	17 25 38	1
B/4	RCT	-	0.6 0.2	23	2
B/5	RCT	3.5	0.6 0.2	23	13
C/1	RCT	4.0	-	23	2
C/2	C-arm	3.8	-	15 23 30	2
C/3*	W II	-	-	-	-
D/1	RCT	3.5	0.6 0.2	23	3

* Indicate W II =without image intensifier RCT= Remote control table

Discussion

From table II it can be seen that 15 fluoroscopy systems were performed at same entrance field size on I.I. and measured under conditions of ABC, though changes of their maximum and minimum values of IIESDR, ESDR and $ESDR_{max}$ are in accordance with those in many other countries.

From table III it can be seen 20 patient weight and technical parameters of fluoroscopic exam setting (such as kV, mA, size of exposure field, fluoroscopic time and number of film) were more different, but the maximum of DAP mean value was 2.1 times more than the minimum. The change of DAP was less than that of three dosimetric performance parameters by far, because many factors affecting patient dose in fluoroscopic exam changed dynamicly, and their overlapping became the total exposure effects of patients.

In respect of establishment to diagnostic reference dose value of fluoroscopic exam many authors have discussed it further since ICRP publication 73 and IAEA Safety Series No 115 were published.[2] [3] [4] They give respectively diagnostic reference dose value to different types of fluoroscopy systems, for example, guide level in IAEA Safety Series No 115 is 25mGy/min to typical ESDR and 100mGy/min to $ESDR_{max}$ for fluoroscopic exam. Britain gave $25Gycm^2$ as DAP reference value for fluoroscopic exam in 1992, revised $7.6Gycm^2$ for digital fluoroscopy system and $15.5Gycm^2$ for none-digital fluoroscopy system in 1998. Countries in North Europe believe that $25Gycm^2$ is valid as reference dose value (DAP) in Barium meal exam.

There are many complicated factors affecting the patient dose in the same exam, such as difference of fluoroscopic time, the number of film and patient size.[5] The author thinks DAP is better than IIESDR and ESDR (or $ESDR_{max}$) for evaluating patient stochastic effects. But in interventional radiological exam, $ESDR_{max}$ of skin for evaluating deterministic effect of skin is better than the other parameters.

Conclusions

First, according to IAEA Safety Series No 115, 16 fluoroscopy systems investigated (except traditional fluoroscopy system C/3) satisfy the guide level. But IAEA Safety Series No 115 just gives typical ESDR (mGy/min) and $ESDR_{max}$, they can not be satisfied with requirements of all kinds of fluoroscopic exam .we should stipulate diagnostic dose guide level (also called diagnostic reference dose level) for every item of fluoroscopic exam.

Secondly, Britain and countries in North Europe make DAP value $25Gycm^2$ as diagnostic

reference dose level. According to the stipulation, we chose 4 fluoroscopy systems to measure the DAP mean values in Barium meal exam for 20 patients, DAP mean value of one fluoroscopy system (A/1) is 27.9Gycm^2 more than 25Gycm^2, but ESDR and $ESDR_{max}$ of this fluoroscopy system are all under the guide level limits of IAEA Safety Series No 115. Thus it can be seen that ESDR and $ESDR_{max}$ reflected the characteristics of equipment, but to evaluate the dose which is accepted by patient in fluoroscopic exam, we still should consider many subjective and objective factors, such as patients'size, fluoroscopic time, the number of films, operator technical skill and so on. It is DAP that synthesized all kinds of affecting factors for patients and got DAP mean value. The author thought DAP value is fit for the diagnostic reference level of patient dose in fluoroscopic exam.

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Table II Measurements of three dosimetric characteristic parameters (IIESDR, ESDR and $ESDR_{max}$) for 16 fluoroscopy systems normal mode of fluoroscopic grid in, field size of 23 cm, with ABC

Hospitals/Room Number	IIESDR Gy/min			ESDR mGy/min			$ESDR_{max}$* mGy/min		
	kV	mA	Measurement	kV	mA	Measurement	kV	mA	Measurement
A/1	85	1.7	108	90	1.7	16.1	124	2.4	36.9
A/2	79	2.0	40	77	2.0	23.5	112	4.0	99.1
A/3	85	1.4	20	79	1.4	7.9	95	1.4	11.4
A/4	76	6.3	27	73	6.8	5.7	125	16	60.8
A/5	88	1.4	44	89	1.4	10.7	121	2.6	33.34
A/6	76	1.6	58	77	1.6	11.4	124	2.4	40.0
A/7	78	0.2	9.0	70	2.0	6.83	100	4.0	26.7
B/1	76	1.3	33	76	1.2	6.5	120	3.0	41.2
B/2	75	2.1	68	78	1.6	9.9	114	2.4	29.4
B/3	71	3.2	36	71	3.0	11.5	111	6.0	58.6
B/4	80	1.5	72	83	1.7	12.0	115	2.3	27.9
B/5	85	0.5	33	80	1.0	3.9	120	1.0	8.2
C/1	70	1.0	21.4	74	1.1	5.5	120	1.9	24.0
C/2	88	2.1	67.8	89	2.1	13.9	125	4.0	55.7
C/3				70	2.0	46.8			
D/1	88	2.0	44.9	74	1.3	5.6	123	2.5	29.4
	Mean value		45.5			10.1			38.8

Table III Value of 20 patient measurements in Barium meal (upper GI) examination

Hospitals/Room Number	Patients number	Patient weight Kg		Fluoroscopic time min		Number of images (films)		DAP value $Gycm^2$	
		Range	Mean value	Range	Mean value	Range	Mean value	Range	Mean value
A/1	5	57-67	47.4	0.57-8.7	4.8	5-12	9.0	8.16-47.89	27.9
B/2	5	54-65	54.6	3.32-6.92	6.1	8-12	9.2	9.84-15.38	13.6
C/1	5	63-70	56.3	3.1-8.7	6.1	3-9	5.2	10.37-35.50	18.8
D/1	5	59-68	51.0	3.2-6.1	4.4	6	6	15.49-31.24	22.0

OCCUPATIONAL DOSES DURING THE INJECTION OF CONTRAST MEDIA IN PEDIATRIC CT PROCEDURES

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1. Abstract

The use of intravenous contrast media by hand or power injection in pediatric CT procedures is being done at King Faisal Specialist Hospital for chest, abdomen and torso diagnostic examinations. This study aims to assess the radiation doses to the nurses during pediatric CT procedures which require them to manually inject the contrast media to the patient during the scan. The length of stay inside the CT room depends on the rate of injection, the type of procedure and the condition of the patient. Thermoluminescent dosimeters, worn by the nurses during pediatric CT examinations, were deployed for three successive months in two CT rooms. Results showed that the average dose per pediatric case to the head region and the hands were 50 μSv and 80 μSv respectively.

2. Introduction

Computed tomography is widely used in the diagnostic examination of adult and pediatric patients when the use of general radiography and fluoroscopy are found to be ineffective. However, radiation dose burden to the patient is high compared to general x-ray examinations [1]. Radiation exposure of the staff is generally not a concern since only the patient stays inside the CT room during examination. For pediatric CT patients where power injection could not be used, it becomes necessary for the nurse to stay inside the room to manually inject the contrast media and that CT scan commences while the last remaining volume of the contrast media is still being injected. This creates a concern among the nursing staff on the amount of radiation dose that they receive from these procedures. Since a protective apron is worn, of particular interest is the dose to the head region and the extremities, specifically the hand.

In the practice of optimization, doses received by patients and staff should be reduced. In order to do this, estimation of the radiation doses can be done to: 1) to demonstrate compliance with dose limits, 2) assist in the implementation of the quality control program, 3) optimize radiological procedures and radiation protection practices, 4) recommend dose reduction techniques and, 5) provide data for references of the user facility and national organizations involved in issuing recommendations and setting regulatory limits [2].

The King Faisal Specialist Hospital & Research Centre, (KFSH&RC) has a well established external radiation monitoring program for its more than 400 radiation workers employed in various radiation facilities including diagnostic radiology, PET/nuclear medicine, radiation oncology and radiopharmaceutical production facility. The Biomedical Physics Department maintains a thermoluminescence dosimetry (TLD) laboratory that employs a Harshaw TLD 6600 automated TLD system for routine personnel monitoring. Standard Harshaw two-element LIF TLD cards are used for whole body monitoring while TLD discs are used for extremity monitoring. Calibration of TLD cards is done in its Secondary Standard Dosimetry Laboratory (SSDL) which has several Cs-137 and Co-60 reference sources of various activities. A standard 30x30x15-cm IAEA slab phantom is used to simulate the human torso for whole body badges and a rod phantom is used to simulate the finger for extremity badges. Calibration is done following the procedures of the International Commission on Radiation Units and Measurements (ICRU) Report No. 47, "Measurements of Dose Equivalents from External Photons and Electron Radiation".

The diagnostic radiology department employs, at any given time, fourteen nurses who are rotated to its various sub units such as CT/MRI, fluoroscopy/angiography and general radiography. Results of personnel monitoring show that the annual doses received by the radiology nursing staff are generally between 2 and 5 mSv.

Pediatric CT procedures are done in either of its two available CT units, a GE Hi-Speed and a Siemens Somatom Plus 4. CT procedures follow standard protocols for adult and pediatric patients. There are procedures that require either hand or power

injection of the contrast medium by nurses. Hand injection time ranges from 35 to 50 seconds depending on the type of procedures and the size of the needle used (10cc or 20 cc). For patients whose weights are more than 35 kg, power injection is used. The rate of injection for a gauge 20 needle used at the antecubital fossa is 2 cc/sec and for a gauge 22 needle used at the antecubital fossa or wrist or hand, it has an injection rate of 1.5 cc/sec [3]. Some of the procedures require that CT scanning be started during injection of the remaining volume of contrast medium.
Data of direct dose measurements are currently not available. This study aims to determine the amount of doses received by the nursing staff during pediatric CT procedures and ascertain its contribution to the total monthly doses due to other radiological procedures.

2.1. Materials & Methods

A set of TLD badges consisting of one whole body badge and one TLD ring used for routine personnel monitoring, is deployed in each of the two-CT rooms. The nurses are instructed to wear these badges (aside from the regular TLD badges issued to them) whenever they perform pediatric procedures. The whole body badge is to be worn at the collar level outside the protective apron while the TLD ring, at the middle finger of the hand that is used for injection, at the dorsal side. Deployment of these TLD badges is done for three successive months, read-out and dose evaluation are done monthly.

A survey form is also issued to each of the two CT rooms wherein the nurse has to write the type of pediatric procedure, the kVp and the mA used, the number of CT slices and the approximate time that the nurse stayed in the room during the scan. Verification of the data entry is made by actual observations of the procedures in the two rooms. The average number of cases per month and the average length of stay per procedure are determined.

Deploying a single TLD badge to be used by all the nurses for all pediatric cases in each CT room would not allow us to determine the dose variation from one nurse to another or from different type of procedures. However, this would allow us to determine the total dose resulting from all pediatric cases performed in a particular CT room for a month. If we know the total number of pediatric cases for that month, we would then be able to estimate the average dose to a nurse per pediatric case.

Scatter radiation measurement at selected locations inside the CT room was also done using the Radcal Model 1515 with 180-cc ionization chamber. A 32-cm polyethylene body phantom simulates the patient and the radiographic factors used are 120 kVp, 220 mA and 27 second scan time. A map of air kerma is shown in Figure 1.0.

3. Results and Discussion

The pediatric CT procedures where the nurses do the injection even when scanning has started are the following: chest, chest with head and neck, chest with abdomen and pelvis, abdomen with pelvis, and chest with liver . Scanning starts at the last 5 to 10 seconds of the injection time, depending on the type of procedure. However, the length of stay inside the room varies from one nurse to the other depending on the rate of injection and the condition of the patient. The total number of cases per procedure for the three-month and the average length of stay inside the CT room during scanning per procedure is given in Table I. It can be seen that examinations of chest with abdomen and pelvis and chest with liver tend to give the longest length of the nurse's stay inside the CT rooms during scan. A 120 kVp and 200 or 220 mA are used for all pediatric procedures.

Table I. Number of cases for selected pediatric CT procedures during 3 successive months and the average length of stay of the nurse inside the room during the scan.

Procedure	Total No. of Cases for 2 CT rooms	Approximate Time of Stay Inside the CT Room (seconds)
Chest	24	5-29
Chest with head & neck	3	15-30
Chest with abdomen & pelvis	41	10-60
Abdomen and pelvis	22	10-45
Chest and liver	6	16-31
Total cases	96	

The total number of pediatric cases per month and the doses received by the "deployed" TLD badges are given in Table II. It can be seen that the average dose that the nurse would receive in the head region per pediatric case is about 50 μSv, and in the hand, about 80 μSv.

Table II. Number of pediatric cases per month and the doses received by "deployed" TLD badges in two CT rooms

Period	Number of cases	Dose (mSv) to "Deployed" TLD Badges		Estimated Dose (μSv) to the Nurse per Case	
		3. Collar Level	Finger	3. Head Region	Finger
1st Month	42	1.65	3.25	40	77
2nd Month	16	1.24		78	
3rd Month	38	0.95	2.95	25	78
Average	32	1.28	3.1	48	78

The scatter radiation measurements show that the highest obtained air kerma of 25 mR is at about 0.8 m from the central beam axis. It would be possible that the nurse be positioned at this location during the injection. The air kerma profile is shown in Figure 1. The air kerma profile shows where the nurses could position themselves for a lower exposure.

Figure 2 shows the average monthly doses, as well as the highest dose, received by the radiology nursing staff, taken from personnel dose records. It can be seen that a radiology nurse generally receives a monthly dose of around 0.2 to 0.5 mSv. It should be noted that a protective apron is worn and that the TLD badge is worn at the collar level outside the apron. This monthly dose therefore, does not represent the effective dose. NCRP recommends the methods to be used in estimating the effective dose based on a single TLD worn outside the apron or when two TLD badges are worn [4].

Based on the monthly number of pediatric cases, it can be assumed that each nurse in diagnostic radiology would handle an average of 4 pediatric cases per month. The dose received by each nurse due to these cases would be about 0.1 to 0.2 mSv. This represents about 20 to 50 % of the total monthly dose received by a nurse working in diagnostic radiology.

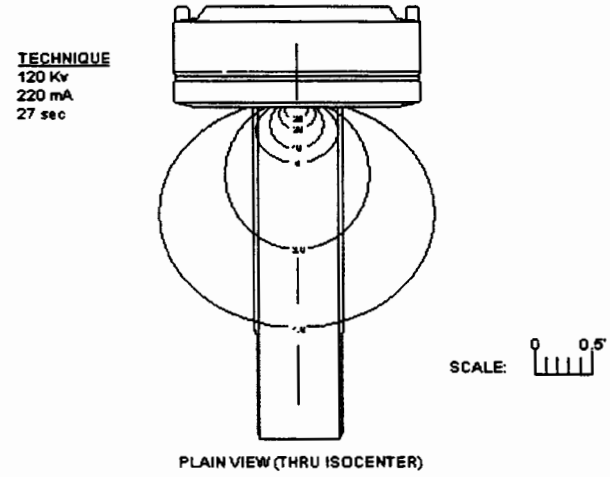

Fig. 1 Air kerma profile of the scatter radiation when a body phantom is irradiated.

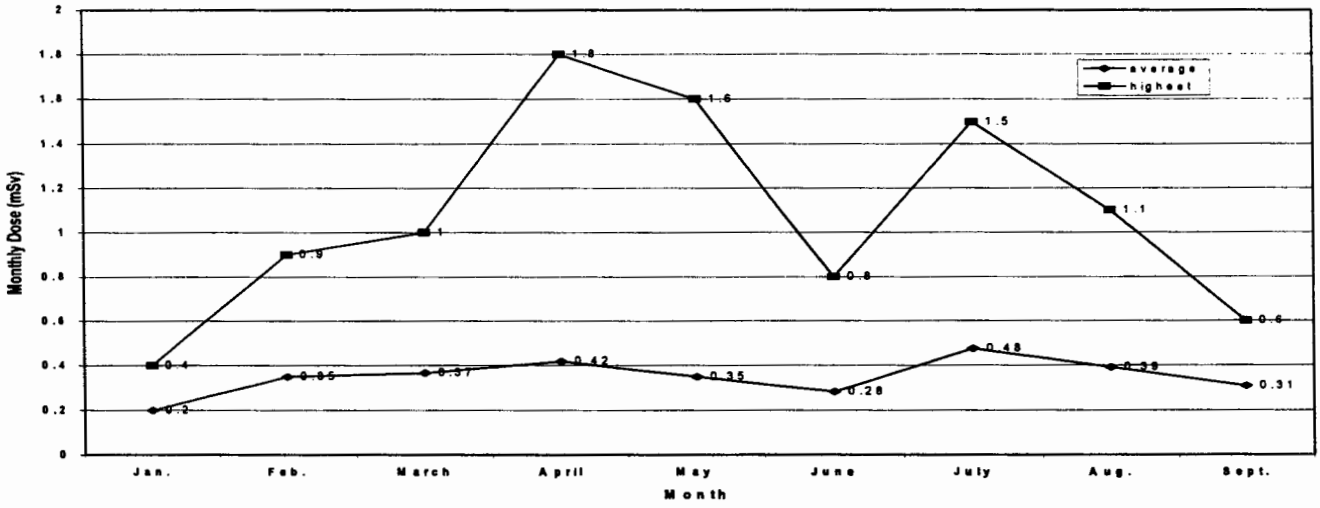

Fig.2 Monthly doses received by the nursing staff of the radiology department from January to September 2000

4. Conclusion

The dose received by the nurses doing the injection to pediatric CT patients could be comparable to the dose received by nurses doing other radiological procedures. The dose to the pediatric cases can be as high as 1 mSv if the nurse handles more than 10 cases per month. The monthly reported doses for nursing staff can be as high as 1.8 mSv. Factors affecting the amount of dose received are: number of cases done, the length of stay inside the room, radiographic factors used and location of the nurses. More study is needed in this area in order to reduce the dose to the patient and staff.

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PREVENTIVE FOOD ADDITIVES FOR PROTECTION IN MEDIAL RADIOLOGY

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Development of radioprotective substance for prevention and treatment of acute radiation effect in still important not only for accidental overexposure but also for protection of patients in radiotherapy and sometime for personnel especially in interventional radiology. The recent progress (achievement) in treatment of skin radiation reactions now is accompanied by introducing of new therapeutic substances for prevention and treatment for whole organism. Comparative study of Biologically active food additives includes the research of synthetic (glutapyron , dieton), natural product (feocarpine, clamine), and also natural foods rich by therapeutic active substances. The anticancerogenic effects of such substances was studied for group of high risk exposed individuals. The use of food additives demonstrated therapeutic effects for haemopoetic system, radiation injuries. The feocarpin was effective for blood stem cells and prevented the acute radiation changes in blood, promote the recovery processed and stabilize the haemopoetic system in late post radiation period. The glutapyrone increased the effects of feocarpine in minimal amounts in radiation. All these preparations are non-toxic and economically suitable for mass distridution as food additive for general public. Glutapyrone-like substance has been found in quail eggs and with similar effectiveness might be used in ration of high risk groups. Life-span and reduction of cancer mortality was found in the experiments and pilot studies in limited population groups.

The data obtained on positive effects of this class of food additives establish the basis for practical application in protection of patients and in occupational groups.

X-Ray Exposure in Pediatric Radiology

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Diagnostic medical X-ray examinations give the main contribution in over background exposure of population. At the same time namely here concentrated maximum possibilitys for reducing of radiation exposure. In order realised this possibilites it is necessary to have the complete dose information about radiation exposure of patients in radiology. The contribution of children exposure in common is very important. It's unestimations lead to understating adult exposure and overstating exposure of all population [1].

For this purpose effective and organ doses at X-ray examinations in children's five ages (0,1,5,10,15 year) and both sex determined by measuring and calculation methods [2]. Calculations was basic on the modification of method Monte-Karlo. It was made spesialized programm for that. Calculated data was verifyed by experimental measurings on the child phantoms. For this was design and make heterogenous antropomorphous phantoms as much as possible realistic [3]. In this phantom are determined averangement, dimensions and forms of the 16 internal organs. Dosimetric child phantoms are made of plastic wich is equivalent to averaged biological soft tissue by element composition, density and linear attenyation coefficient of radiation. Phantoms contain tissue-, skeleton- and lung-equivalent plastic.

Since it is important for assesment of the varidity of utilization of the collective dose as a measure of detriment for medical irradiation. We investigate some radiation indexes in hospitals of St.-Petersburg. Some of the received data presented in tabl.

Table

Summary index of pediatric radiology in St.-Petersburg

Index	Year			
	1996	1997	1998	1999
Number procedure per 1000 child in:				
radiology	340	505	536	475
dental	6	6	4	4
nuclear medicine	20	8	11	6

ultrasound	274	338	390	432
All	**640**	**857**	**941**	**917**
Annual individual effective dose, mkSv in:				
radiology	38	94	87	70
dental	0,2	0,2	0,1	0,1
nuclear medicine	101	38	56	31
All	**139**	**132**	**143**	**102**

On this information was made data base. It's necessary for calculated individual and collective doses from ages and type investigation (doses from sex differ negligible) in Sankt-Petersburg. It be seen, collective dose give the children of oldest age group - 15 year (38%). On type investigation maximum contribution give investigations of spine (47,9%), lung (20,5%), hip joint (8,9%) and scull (6,8%). Together this investigations give 84,1% from all collective dose of children in X-ray. Extrapolation collective dose was state for the value for Russia. And then on this and another data with approximate would be calculated indexes from pediatric radiology for all children sof Russia, including radiation dose.

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THE ANALYSIS AND CHARACTERISTICS OF MEDICAL IRRADIATION IN ST.-PETERSBURG

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We disposed of some considerable facts about the characteristics of medical radiation exposure of the population of Russia in the whole country and in separate regions. It was interesting to retrace such appropriatenesses medical radiation exposure at the level of separate of hospitals. There was worked up a special computer programme for this research. With the help of it many quantitive and qualitative indices of radiation diagnostics could be calculated including the doze of irradiation of the patients and the population of St.Petersburg.

The indices must be calculated for the population unit, otherwise the information is objective and can be comparad with the analogous facts for the separate regions and the whole country. As the number of the population for different kinds of hospitals was unknown, so there was worked up special methods, which allowed to know this number.

All medical hospitals were devided into several levels for comfortable presentation of material, namely a hospital level, a hospital-polyclinic level and an out-patients' clinic level. For the first time the information about irradiation of children was obtained. The basic indices are shown in the table 1.

The table1

Basic indices of radiation exposure for different kinds of hospitals

Index	Hospital	Hospital-polyclinic	Polyclinic	All	Child
The number of X-ray procedures per thousand population	204	576	1054	1833	475
The number of					

X-ray equipment per million population	81	167	218	466	330
The number of physicians per million population	980	1730	3360	6060	5450
The number of radiologists per million population	30	70	110	210	121
Annual individual effective dose per caput ,mSv	0.26	0.39	0.67	1.18	0.07

As can see, the numbers of radiation procedures for 1000 population and for children in hospitals, hospital-polyclinics and polyclinics are greatly different and andaccordingly make 200, 570, 1050 and 475, in all it is 1800.

The average individual dose for these hospitals is also different and accordingly makes 0.13, 0.40, 0.67 and 0.07 mSv, at an average it is 1.20 mSv.

This method allowed to apprise the level of hospitals' providing with X-ray equipment and radiologists.

Detalied information about the structure of exposure is shown in the table2. It allowed to define the radiation diagnostics situation in St.Petersburg.

The table2

Detalied structure of radiation exposure in St.Petersburg (%)

Index	Quantyti	Contribution (%)	Number per 1000 populations
All diagnostic	**10994,9**	**99,9**	**2334**
Radiology	**9149,1**	**83,3**	**1950**
Fluoroscopy	162,9	1,8	35
Radiography	6146,7	67,2	1310
Photofluorography:			
Diagnostic	2839,5	31,0	605
Screening	1831,5	20,0	390

Chest	3684,4	40,3	785
Digestive organs	651,7	7,1	140
Sceleton	2907,0	31,8	620
Other *	1906,0	20,8	406
Dental	956,6	10,6	205
Mammography	34,2	0,4	7
Angiography	6,8	0,2	1
Urography	32,5	1,1	7
CT	55,0	1,8	12
Nuclear medicine	**167,0**	**1,5**	**35,5**
Ultrasaund diagnostic	**1678,8**	**15,2**	**356**
Radiation therapy	**11,1**	**0,1**	**2,4**
All	**11006,0**	**100**	**2337**

Thus the research allowes to create the base of facts about numerous parameters of radiation diagnostics and the irradiation doze of patients and population. It allowes also to apprise the efficiency of work of different institutions. The health protection officials could make desidions of organization and take control on the basis of these facts.

RADIATION PROTECTION REGULATION IN MEDICAL RADIOLOGY IN RUSSIA

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During last 5 years various regulatory documents have been developed in Russia to reduce medical exposure of population (in Russia at 1 mSv of annual individual effective evaluated dose) starting from " Law on Radiological Safety of population " (1997). By this law the system of radiation safety in medicine for patients and medical personnel provides the rights of the patient to refuse the radiological procedure with exception of obtaining information on dangerous contagious diseases of social importance, provision of information on radiation dose levels for an individual and whole population, which include the information on expected dose from any radiological procedures and relevant health risk. The document was issued on practical implementation of law - " National basic safety standard - 90 ", which include annual limits for mass screening as one mSv. The same value is applied to biomedical research without direct profit for patient health and forensic radiological investigations. In nuclear medicine the limits for releases of patients with incorporated radiopharmaceuticals from hospitals have been established. Under these rules all personnel working in exposure areas (e.g. surgeons) belongs to the category "B-personnel" with accepted limit of ¼ of limits of personnel of "A-category", approximately 5 mSv of annual effective dose and equivalent dose for skin and hands -125 mSv/year. In case if such requirements could not be guaranteed the personnel should be transferred into the A-category. In year 2000 "Basic Sanitary Rules for radiation Safety" have been issued, as well as Rules for the design of X-ray facilities and performance of radiological (X-ray) examination which include requirements for the provision of patient safety and justification for required examinations by physicians for any radiological procedure , as well as provision of dosimetric control, individual dose assessment and registration of accumulated dose from all types of radiation exposure with all necessary additional radiation protection measures recommended and required.

NEW RUSSIAN X-RAY SYSTEMS FOR MEDICINE

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The portable medical X-ray systems **"dental"** and **"diagnostic"** are intended for use by the doctors both in clinics and in private consulting rooms. The main distinctive feature of the systems is the very small focus spot size that permits to improve considerable the quality of X-ray films and to make the exposure for a radiation with a direct X-ray magnification if necessary. As a result it is possible to disclose on X-ray films the details which are absolutely inaccessible for disclosing with the use of usual X-ray systems. The systems are executed as monoblocks and consists of tubehead, power supply unit (including control panel), special support and interconnection cable. Maximum value of voltage within the cable is not more, than 200 V. The control panel contains microprocessors and permits to program all the parameters of exposition - tube voltage, tube current, time of a exposition as well as whole process of preparation of a system to work.

"Пардус-01" - small focus dental X-ray system. Parameters of the system: U_{tube} - 50÷90 kV, I_{tube} - 100 μA, Øfocus - 0,2÷0,3 mm, duty cycle - 100 %. Typical time of exposition - 1 sec (usual medical X-ray film fluoroscopic screens). Weight: tubehead - 4,5 kg, power supply unit - 2,5 kg, support - 22 kg.

Advantages of the system in comparison with analogues. The system is executed under the original constructive circuit with the use of X-ray tube with a remote flat anode of a small diameter. To produce X-ray film (to exposure to a radiation) of teeth the remote anode (the element of tubehead by a diameter of 12 mm and a length of 130 mm) is inserted into the patient's mouth cavity. X-ray cartridge with the X-ray film possessing central aperture for pass of a anode, is applied to the denture outside. Radiation from an anode passes from a mouth cavity outside through the denture and is fixed on a film. As a result the reception of panoramic and aimed-panoramic X-ray films including both dentures simultaneously is possible without use of an orto-pantomography system. Owing to small focus spot size the quality of X-ray films is well above and radiation load on patient and the staff is reduced in 5 times and

more. The X-ray system is certificated by Public Health Service Ministry of Russia and is recommended to use in medical practice.

"Пардус-150" - microfocus diagnostic X-ray system. Parameters of the system: U_{tube} - 50 ÷ 130 kV, I_{tube} - 0 ÷ 300 μA, Øfocus < 100 μm. Duty cycle: exposition time not more than 5 sec with a break not less than 1 min. Typical time of exposition - 1÷5 sec (usual medical X-ray film with fluoroscopic screens). Weight: tubehead - 8,5 kg, power supply unit - 9 kg, support - 22 - 25 kg.

Advantages of the system in comparison with analogues. The system is designed for producing X-ray films with a direct X-ray increase up to 8^X. Due to the small focus spot size the structures with the dimensions less than 0,2 mm are easily distinguished on such X-ray films and it is very important for diagnostics of a number of illnesses. As a whole the quality of X-ray films is essentially above and the radiation load on patient and staff is sharply reduced. At present the system is under the process of certification and reception of the sanction of Public Health Service Ministry of Russia for use in medical practice.

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Conceptually against Individual dose

PARAMETER ESTIMATION AND COMPARTMENTAL MODELLING FOR INDIVIDUALIZATION OF THERAPEUTIC DOSAGE OF RADIOPHARMACEUTICALS.

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Abstract
A successful application of radiopharmaceuticals for therapy requires a patient-specific optimization of the administration activity. Intention of this contribution is to show how this is possible with a relatively limited effort, by combining an optimized experimental schedule for the collection of the anatomic and physiological data of interest and a rigorous mathematical analysis. The benefits of such an optimization will concern not only the success of the therapy, but also the radiological protection of the patients and could even be translated in a more cost-effective usage of the radiopharmaceutical available.

1. Introduction

The therapeutic use of radiopharmaceuticals requires generally the administration of relatively large activities. A realistic dosimetric evaluation is therefore desirable in the effort to optimize the dose to the target organ while sparing the healthy tissues.
The determination of internal dose is however a rather complicated process, which requires the knowledge of several pieces of information: the anatomical features of the irradiated regions, the fractional uptake of the administered substance into these tissues with the characteristic retention times, as well as the kinetics of the excretion process, in order to be able to estimate the dose burden to the organs of the gastroinestinal and of the urinary tracts.
Since the anatomical and biokinetic parameters may differ remarkably between subjects, the evaluation of the correct treatment strategy should be performed on an individual basis. However, the performance of preliminary measurements aimed at the determination of the physiological parameters for each individual undergoing therapy could be a significant complication for the daily routine of an ordinary Nuclear Medicine Service.
It is therefore desirable to devise easy methods for the individualization of the radiometabolic treatment.

2. Patient-specific dose: a case study.

Let's consider patients with autonomous thyroid nodule (ATN) being treated with ^{131}I. In these subjects, the uptake of the radiopharmaceutical in extranodular tissue might be relevant, and it is in fact considered responsible of the relatively high prevalence of hypothyroidism occurring after treatment [1]. In this specific case, a correct knowledge of the anatomy of the regions involved, of the fractional uptake into the nodule and into the healthy lobe and of the elimination from these tissues may provide a reliable estimate of the dose received by each of them. On this basis, the activity to administer to each ATN patient may be determined, and the corresponding dose to the extranodular tissue evaluated, thus providing the clinician a patient-specific picture for the evaluation of the possible consequences of the therapy.
Matheoud et al. [2] have studied sixteen patients with ATN, estimating thyroid morphological parameters and iodine kinetics from images of the neck taken at 6 different times between 2 and 120 hours after injection of a tracer activity of ^{123}I. Thyroid uptake in the nodule and in the lobe respectively were obtained by fitting the uptake function

$$U(t)=\frac{U_0\lambda_{in}}{\lambda_{eff}-\lambda_{in}}\left(e^{-\lambda_{in}t}-e^{-\lambda_{eff}t}\right) \qquad (1)$$

to the corresponding data set in order to obtain the values of unknown parameters U_0 (the fraction of administered iodine transferred to the nodule and the lobe respectively), λ_{in} (rate of uptake) and λ_{eff} (effective decay constant, which is the sum of the rates of biological decay and of radioactive decay).
Recalling that the dose to the nodule and to the lobe can be estimated using the MIRD formula [3]:

$$\overline{D} = \tilde{A}S = S\int_0^{\infty} A_0 U(t)dt = \frac{A_0 U_0 S}{\lambda_{eff}} \qquad (2)$$

being S the mean absorbed dose per unity cumulated activity $\tilde{A}$, it was possible from (2) to determine the activity A_0 to be administered in order to release in the nodule the desired dose $\overline{D}$. Consequently, the corresponding radiation dose to the healthy extranodular tissue were evaluated. The parameters, and therefore the optimum dosages required by each subject, showed a great variability, and this fact stresses the importance of tools which enable to individualize the treatment planning.
The possibility of reducing the number of image acquisitions to only 3 was also investigated, in order to make the procedure more easily applicable in the routine. The estimates for the optimum dosage calculated with the 3-point technique deviate in all cases but one less than 5% from those obtained from the 6-point-technique. The deviations of the dose to the lobe are slightly higher, however they never exceed 15%. The ordinary method with only one uptake measurement at 24 hours with a supposedly known dismission rate provides on the contrary estimates differing up to 70% from the more correct ones obtained with the 6-point-method.
The data collected as described above can also be analyzed according to a simple compartment model, like the one shown in Figure 1.

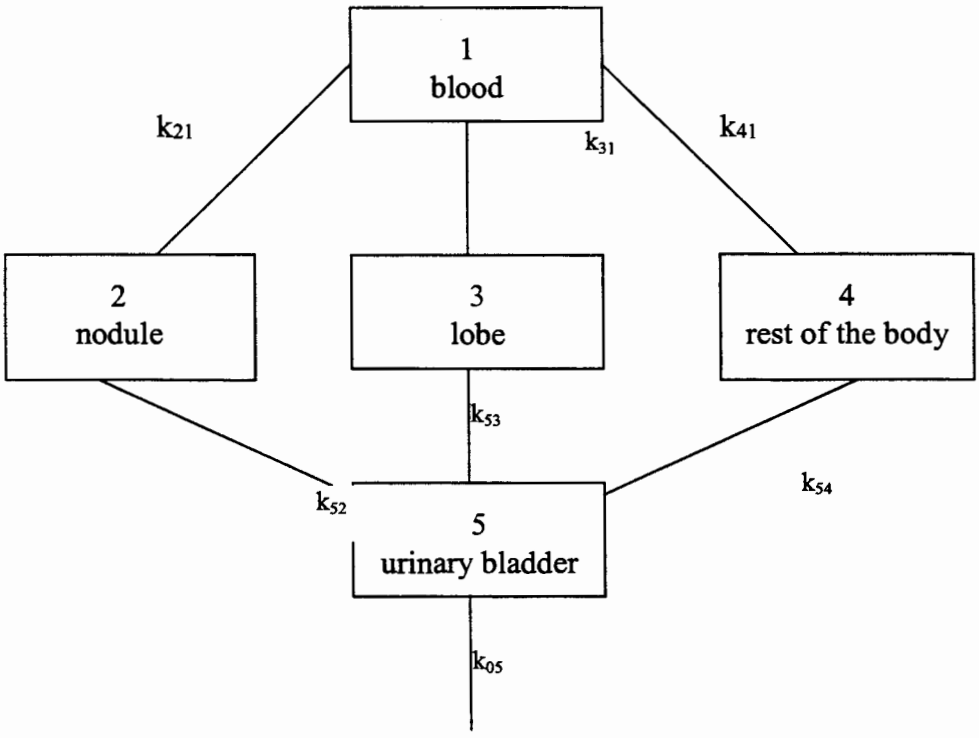

Figure 1. Model for the kinetics of ^{131}I in ATN patients.

The model tries to give a comprehensive description of the processes involved: the injected activity is distributed between the nodule, the lobe and the rest of the body, and then it is eliminated through the renal pathway. The exchange of material between compartments is considered to be regulated by a first-order kinetics. Under this assumption, this system provides for the compartments nodule and lobe equations which are mathematically equivalent to (1), where now the λ's are combinations of the model parameters k_{ij}. For example, $\lambda_{in} = k_{21}+k_{31}+k_{41}$ for lobe and nodule (and also for compartment 4), that is λ_{in} assumes the same numerical value. Indeed, for each patient, the λ_{in} found with the single fit procedure turned out to assume values which can be considered equivalent within the uncertainties.

The analysis of data with compartmental models is no more complicated than single curve fits. PC-based easy-to-use software packages are available on the market (i.e. SAAM[+], Modelmaker[§]). They enable to define a model, to associate the experimental data (e.g., the uptake measurements in the nodule and in the lobe) to the corresponding model prediction, to find the best values of the characteristic parameters by means of a least-square fitting procedure of the whole set of data simultaneously, and also to perform calculations (e.g., the cumulated activity) without the need to derive the analytical mathematical expression (which for complex models can be quite difficult to derive). The advantage to use a model is that it provides a physiologically more realistic picture of the distribution of the drug in the organs, and it may enable a more correct evaluation of the dose to other organs which are not directly involved in the therapy.

For example, the data of the nodule and lobe uptake will enable to derive for each patient the values of the parameters k_{21}, k_{31}, k_{52} and k_{53}. By assuming for the parameter k_{54} (elimination from the compartment "rest of the body") a value of 0.087 h^{-1}, as suggested by ICRP [4], and by taking the process of radioactive decay into consideration, it is then possible to calculate, for each patient, the activity cumulated in the urinary bladder, and thus obtain a more realistic estimate of the dose to this organ and to the sorrounding ones. Even more, as often the urine excreted by the patients in the first hours or day is collected in the hospital for safety reason, it is possible to perform measurements of the amount of drug excreted and use these additional data for the model fitting. Although the dose to the bladder and the sorrounding organs is usually not relevant for the justification and optimization of the therapy, its determination can be in any case of use and also be recorded for any follow-up of the patients.

3. Conclusions

As this simple example shows, the improvement and individualization of a treatment planning may be obtained with a relatively limited effort combining an optimized experimental schedule and a rigorous although simple mathematical analysis. The advantages of such effort will be reflected not only in the success of the therapy, but also in the radiological protection of the patients and even in a more rational and cost-effective use of the resources (i.e., of the radioactive material) available in a Nuclear Medicine Department.

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METODOLOGÍA PARA LA APLICACIÓN DE LAS TÉCNICAS DE ANÁLISIS PROBABILISTA DE SEGURIDAD (APS) A LAS UNIDADES DE COBALTOTERAPIA EN CUBA

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Resumen

La amplia utilización de las técnicas de Análisis Probabilista de Seguridad (APS) en el sector nucleoenergético durante las pasadas dos décadas y los positivos resultados obtenidos para la toma de decisiones en materia de seguridad, como complemento de los métodos deterministas, han incentivado su utilización en el resto de las aplicaciones de la esfera nuclear. Son cada vez más frecuentes los documentos de prestigiosas instituciones internacionales que resumen las investigaciones realizadas en este campo y promueven su utilización en diferentes instalaciones radiactivas. Aunque aún sin un carácter mandatorio, las nuevas regulaciones de seguridad radiológica también promueven la utilización completa o parcial de las técnicas de APS en la evaluación de seguridad de las diferentes prácticas. Asimismo, el Organismo Internacional de Energía Atómica (OIEA), a través de diversos programas en los que Cuba se ha insertado, está tomando un grupo de acciones para que la comunidad nuclear priorice la aplicación de las técnicas probabilistas de riesgos en la evaluación y toma de decisiones en materia de seguridad. Sin embargo, a pesar de ser una metodología con probada eficacia en el sector nucleoenergético, el hecho de que en ninguna instalación radiactiva se haya realizado aún un estudio completo de APS, hace que existan determinados aspectos metodológicos que requieran profundizarse y adaptarse para la aplicación de dichas técnicas. En el presente trabajo se discuten los principales elementos tenidos en cuenta para la utilización de los Análisis Probabilistas de Seguridad en la evaluación de la seguridad de las unidades de cobaltoterapia de Cuba y se presenta, como parte de los resultados de la primera etapa del Estudio, la Guía Metodológica que está siendo utilizada en un Contrato de Investigación del OIEA que actualmente realiza el colectivo de autores del CNSN, de conjunto con otros especialistas del Ministerio de Salud Pública (MINSAP).

Introducción.

La evaluación de la seguridad ha descansado tradicionalmente en el enfoque prescriptivo, es decir, la evaluación del cumplimiento de determinados códigos y normas que resumen los resultados de la evidencia histórica, la investigación y el desarrollo en un momento dado, así como la comprobación mediante análisis deterministas en los que se utilizan las hipótesis más desfavorables para comprobar que ante el peor accidente previsible no ocurren consecuencias radiológicas graves y por tanto se garantiza que los resultados de las evaluaciones queden del lado de la seguridad. Este enfoque tiene a favor que la demostración de correspondencia es relativamente directa, a la vez que asegura niveles aceptables de seguridad, integridad y fiabilidad. El método determinista es incuestionable, sin embargo posee limitaciones que hacen conveniente el uso de un enfoque complementario para la evaluación. Entre estas limitaciones están:

- Las **regulaciones** descansan en requisitos precisos y detallados, por lo que **tienen una rigidez intrínseca** que puede ser rápidamente rebasada por nuevos desarrollos

tecnológicos.

- Los **factores humanos y organizacionales** que influyen en la seguridad **son poco propensos a la evaluación prescriptiva.**
- El enfoque prescriptivo **puede inhibir la innovación** y la búsqueda de soluciones más óptimas para incrementar la seguridad.
- Posee el riesgo de que el diseñador o el operador puede no entender la esencia o razón de ser de las regulaciones, preocupándose simplemente por su cumplimiento. Esto es, este enfoque promueve una ***"cultura de cumplimiento"*** más que la búsqueda de la seguridad máxima factible por los medios mejores posibles.

Existe otro enfoque complementario de evaluación de la seguridad denominado "*Análisis Probabilista de Seguridad (APS)*", que utiliza herramientas conceptuales y matemáticas para realizar una investigación sistemática, exhaustiva y estructurada de los diferentes escenarios de riesgos que pueden conducir a un evento no deseado (*secuencias accidentales*) a partir de la ocurrencia de fallos de equipos o errores humanos (*sucesos iniciadores de accidentes*).

En las últimas dos décadas, el APS ha sido ampliamente utilizado en el sector nucleoenergético, realizándose decenas de estudio en los países con centrales nucleares, y obteniendo positivos resultados para la toma de decisiones en materia de seguridad, como complemento de los métodos deterministas.

El principal objetivo de un APS consiste en proporcionar información cualitativa y cuantitativa acerca de las interioridades del diseño y funcionamiento de una instalación, incluyendo la identificación de los contribuyentes al riesgo y comparación de opciones para incrementar la seguridad.

Es decir, la finalidad de un APS se puede resumir en:

- Determinar y precisar las combinaciones de sucesos que pueden conducir a un accidente o evento no deseado;
- Evaluar la probabilidad de que se produzca cada combinación;
- Evaluar las consecuencias.

Con este fin, la metodología de APS integra información sobre el diseño, practicas de operación y funcionamiento, historial operacional, fiabilidad de equipos y componentes, comportamiento humano, fenómenos favorables a un accidente y efectos potenciales.

Toda esta información es utilizada para lograr que los posibles incidentes, deficiencias, errores y vulnerabilidades de la instalación, proporcionen un panorama equilibrado de su efecto sobre la seguridad, así como la importancia relativa de las contribuciones al riesgo de las secuencias de accidente que podrían iniciarse a causa de fallos en el equipo o las modalidades de operación.

Metodología para la ejecución del APS

Para cualquier instalación o práctica, la realización de un Análisis Probabilista de Seguridad comprende las 6 etapas fundamentales que se representan en el diagrama en bloques de la figura 1.

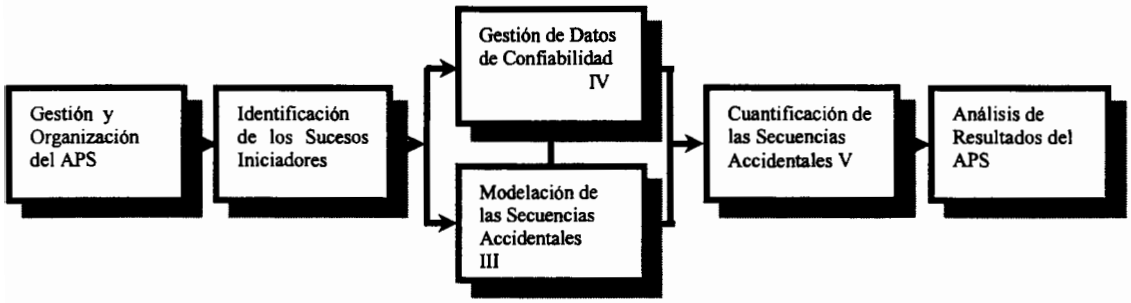

Figura 1. Pasos para la Ejecución del APS

Aunque en principio los métodos de APS pueden ser aplicados a cualquier tipo de instalación, existen un grupo de aspectos que requieren profundizarse para garantizar su plena utilización metodológica, teniendo en cuenta los siguientes elementos:

1. Alcance del estudio
2. Naturaleza y complejidad de la instalación,
3. Grado de introducción del APS en instalaciones similares,
4. Disponibilidad y detalle de los análisis deterministas de seguridad,
5. Idoneidad de los modelos para la instalación
6. Disponibilidad y calidad de los datos de fiabilidad
7. Incidencia e importancia del factor humano en las secuencias accidentales a estudiar.

Especial atención en la aplicación de la filosofía del APS a la práctica de cobaltoterapia, máxime cuando el Estudio está enfocado hacia la seguridad del paciente, debe prestarse a hecho de que muchas de las características de las exposiciones potenciales que se identifiquen serán mayoritariamente generadas por actuaciones humanas, por lo que el APS, en gran medida será un análisis específico y detallado de los factores humanos que intervienen en las secuencias accidentales.

Teniendo en cuenta este aspecto, y las limitaciones que existen para la estimación de las probabilidades de errores humanos; y considerando que es muy elevado el número de posibles actuaciones humanas, el APS deberá utilizar con el mayor nivel de detalle posible las técnicas cualitativas de identificación de peligros y la evaluación de las incertidumbres en las probabilidades asignadas.

Es por esta razón, que a pesar de la existencia de documentos metodológicos para la realización de un APS, y de su utilidad práctica, se han adaptado para la ejecución de los Análisis Probabilista de Seguridad a las prácticas de cobaltoterapia en Cuba las diferentes

etapas para la aplicación del Estudio, según se presenta en el diagrama en bloques de la figura 2.

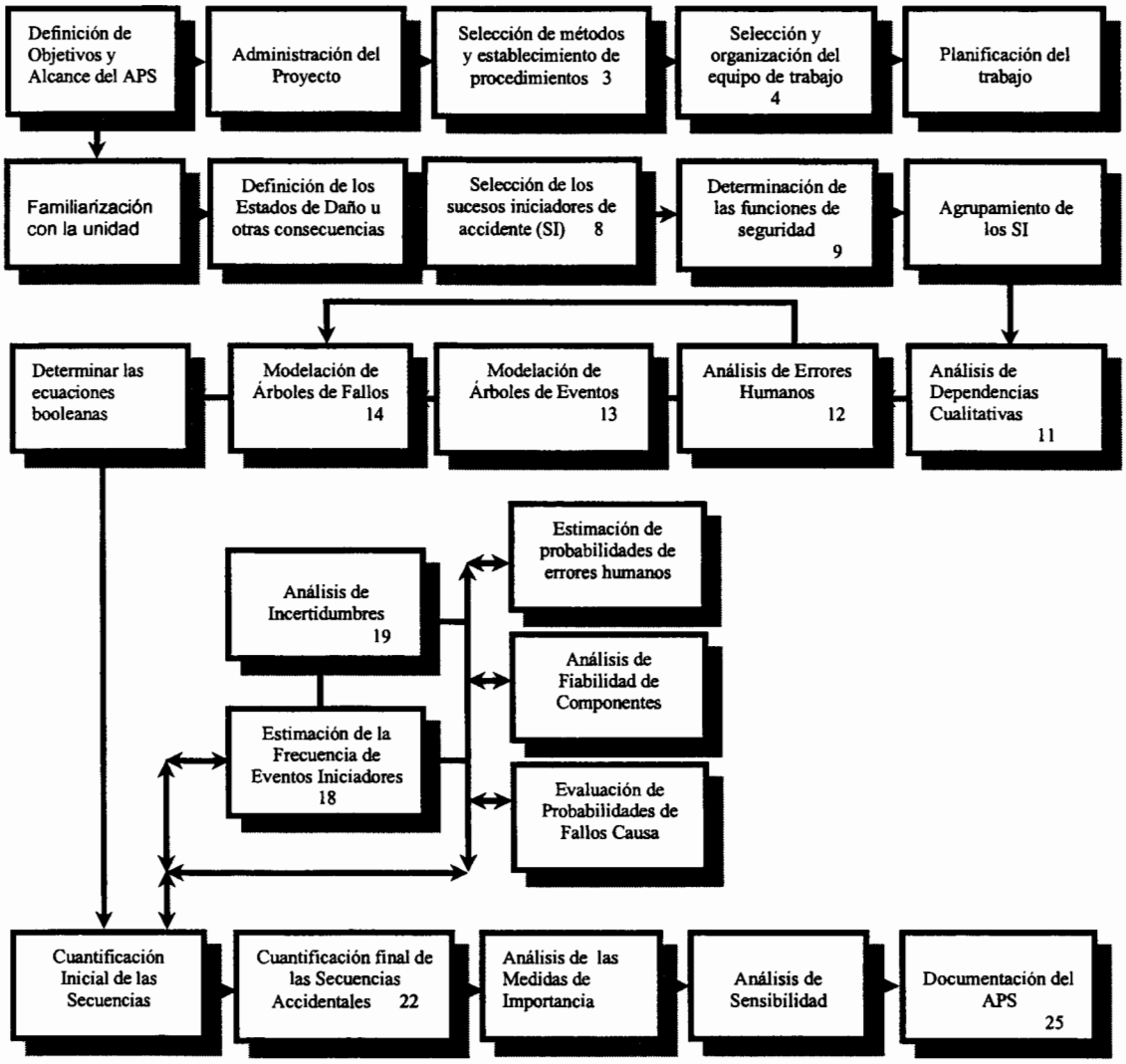

Figura 2. Diagrama en bloques de la Guía Metodológica para la ejecución del APS a la práctica de cobaltoterapia en Cuba

En sentido general, la metodología tiene en cuenta los siguientes puntos:

- Identificación de peligros o accidentes con consecuencias importantes que pueden tener lugar durante el tratamiento con cobaltoterapia *(estado de daño)*
- Identificación de cómo se puede llegar a iniciar las secuencias de sucesos que conlleven a los estados de daño identificados *(sucesos iniciadores de accidente)*. Para ello se combinarán diferentes métodos, que de una forma sistemática y exhaustiva permitan garantizar que la posible ausencia de un suceso iniciador de accidente, no

tendrá un aporte relativo significativo, con respecto a todos los considerados en el Estudio.

- Determinación de los efectos sobre el paciente, el trabajador ocupacionalmente expuesto y el público, a partir del análisis de los modos de fallos de los equipo y los posibles errores humanos en las diferentes etapas del tratamiento con cobaltoterapia
- Desarrollo de los árboles de sucesos que representen las secuencias posibles.
- Análisis, por medio de árboles de fallos de los cabeceros modelados en los árboles de sucesos
- Cuantificación de las probabilidades asociadas a los sucesos iniciadores y a los sucesos básicos en los árboles de fallos
- Análisis de la fiabilidad de las acciones humanas que figuren en los sucesos iniciadores, en los árboles de sucesos o en los árboles de fallos
- Cuantificación de las frecuencias anuales de las diversas secuencias y peligros identificados en el primer paso.

Para esta primera etapa del Estudio, no se realizarán de forma *exprofesa* estudios médicos detallados de los accidentes identificados y las secuencias modeladas, así como no se cuantificarán en términos económicos o de daños humanos las consecuencias consideradas en los estados de daño, por lo que no se integrará el riesgo desde el punto de vista cuantitativo, aunque sí será válido desde el punto de vista cualitativo. Es decir, en esta primera etapa, el estudio solo tendrá un alcance de "*Análisis Probabilista de Seguridad (APS)*" y no de un "*Análisis Probabilista de Riesgo (APR)*"[1].

Conclusiones

El trabajo resume los principales elementos tenidos en cuanta durante la realización de la "Guía Metodológica para la aplicación de las técnicas de Análisis Probabilista de Seguridad (APS) a las unidades de cobaltoterapia en Cuba". Este documento constituye el primer resultado de un proyecto de investigación para la evaluación de la seguridad del paciente durante la práctica de cobaltoterapia en el país.

La metodología incluye la aplicación conjunta de más de 5 técnicas de identificación de riesgos, que posibilitarán el análisis exhaustivo, sistemático y estructurado de la práctica en Cuba

A su vez, la *Guía* podrá ser utilizada por nuestro órgano regulador como material de referencia durante la evaluación de Estudios similares que se realicen en el país como parte del proceso de licenciamiento de las diferentes instalaciones radiactivas.

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[1] En rigor, un Análisis Probabilista de Riesgo se deberá corresponder con la siguiente definición de riesgo:

$$R = \sum_i P_i \cdot \sum_j D_j$$

donde:

P_i: probabilidad de ocurrencia del accidente i

D_j: daño j; consecuencias del accidente, que deberán incluir tanto la salud como las socioeconómicas, y en cuyo cálculo se incluye la magnitud de cada dosis

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BENEFIT AND RISK IN BREAST SCREENING

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Benefit and risk in breast screening

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Abstract

Justification of breast screening in radiation protection terms both for the screened population and on an individual basis is necessary. In this paper the number of cancers detected, and the number of cancers potentially induced by radiation, in the UK National Health Service Breast Screening Programme (NHS BSP) are compared. Detection rates reported up to 1998 are used, with x-ray doses for 1997 and 1998 and breast cancer induction risk factors, stratified by age, recommended by the National Radiological Protection Board in 1994. Cancers detected exceed those potentially induced at all ages from 50 – 64.

The relationship between these cancer numbers and the associated benefit and risk, in terms of breast cancer deaths avoided and induced, is then investigated. Improved values of the Nottingham Prognostic Indicator (NPI) attributed to screening provide one means of doing this. Using this strict criterion the breast-screening programme is also justified in radiation protection terms.

1. Introduction

It is widely considered that breast cancer can be induced by high doses of ionising radiation, such as X rays. The probability or risk of induction is believed to be dependent on dose. The time lapse between exposure to ionising radiation and development of breast cancer is generally agreed to be at least 10 years for women in the screening age group. Breast cancer induction decreases with increasing age at exposure [1].

In a breast-screening programme, the benefits achieved in the form of lives saved or prolonged should clearly exceed the risks arising from any breast cancers that may be induced from the associated radiation exposure. In this context both benefit and risk can only be estimated statistically, so that it is the probability of each which must be compared.

Many attempts to consider the balance between radiation risk and benefit have been published. Most have considered only the numbers of cancers detected and induced, both of which can be estimated with relative confidence (e.g. [2]). Assessing benefit from treatment outcome is a much harder task. Treatment outcome is statistically more difficult to predict, especially in breast cancer, for which 5-year survival is a less reliable indication of "cure" or final outcome than in many other cancers [3].

This paper will consider the latest cancer detection rates and dose estimates, and hence the relative numbers of cancers detected and induced. It will then use treatment outcome data in an attempt to relate those numbers to the balance of benefits and risks.

2. Breast Doses in the NHS BSP

The mean dose to breast glandular tissue (MGD) is generally considered to be the dose quantity most relevant to the risk of radiation induction of breast cancer. Average values of MGD for the NHS BSP have recently been reported by Young and Burch [4], who have found mean dose levels *per film* of 2.03 ± 0.02 mGy for lateral oblique views and 1.65 ± 0.02 mGy for craniocaudal (CC) views. The mean dose *per woman* is slightly higher because a small minority of women have more than one film per view, especially where the larger film size of 24 x 30cm is not available. The corresponding mean doses per woman for single view and two-view screening are 2.14 ± 0.04 and 3.65 ± 0.07 mGy respectively.

Current routine practice in the NHS BSP is to perform two view screening on the first round (ages 50 – 52) and single view screening on subsequent rounds. In the calculations that follow later in this paper, the dose levels for both single and two-view screening will be used for the 50 – 64 year age band.

The highest doses are likely to be received by women with the thickest breasts (around 10cm). These women also require more than one film per view, possibly up to four such films. However, the number of women in this subgroup is extremely small and difficult to predict. Young and Burch [4] report that for oblique films only, one film per thousand exceeded 8.6mGy, and they describe this as the maximum dose per film that may normally be expected. The corresponding dose level for CC films was 7.1mGy, giving a combined normal maximum dose for two-view screening of 15.7mGy at one film per view. Even for the 0.1% of the screened population receiving the highest doses (mainly those having the thickest breasts), the dose should not exceed 20 mGy.

3. Radiation Risk Factors for Breast Cancer Induction

The risk of radiation induction of breast cancer decreases with increasing age of the woman at time of exposure (e.g. [1]). Numerical values for the magnitude of this risk factor are based on work by the National Radiological Protection Board (NRPB), with further subdivision from 10 to 5 year age bands

following discussion with NRPB [2]. Although this data is 5 years old, these estimates of the risk factors are considered to remain the best available for the UK population. They refer to all breast cancers in a female population, not fatal cancers in a mixed population as in some earlier studies, and are given in Table I.

Table I **Radiation Risk Factors For Breast Cancer Induction – UK Female Population**

Age Band	Breast Cancers Induced per Million women per mGy
50-54	13.2
55-59	11.5
60-64	9.4

Screening detection rates in the NHS BSP are reported at annual intervals. Those for the last four years for which figures are available are given in Table II and refer to England rather than the UK [5].

Table II **Cancer Detection Rates in the English Breast Screening Programme (/1,000) [5]**

Age Band	1994-95	1995-96	1996-97	1997-98	Mean
50-54	4.3	4.6	5.0	5.4	4.8
55-59	4.7	4.7	5.0	5.3	4.9
60-64	6.3	5.9	6.0	6.0	6.1
Mean 50-64	5.1	5.1	5.3	5.6	5.3

4. Cancers Detected and Cancers Induced

Table III gives the ratios of cancers detected/induced, using the data from Table II, for three 5-year age bands of the NHS BSP, and for the various dose levels discussed earlier. These ratios are all in double figures, i.e. the cancers detected exceed the numbers induced even for almost all the women in the highest dose subgroup.

Table III **Ratio of Cancers Detected to Cancers Induced at Various Dose Levels**

Age Band	Radiation Dose Levels (mGy)			
	2.14	3.65	11	20
50-54	170	100	33	18
55-59	199	117	39	21
60-64	303	178	59	32

5. Breast Cancer Treatment Outcomes

In many types of cancer, 5-year survival is used as an indicator of outcome because, beyond this interval after initial treatment, life expectancy is restored to that of a normal population of the same age. With breast cancer, however, long-term recurrence is such that this position may not be achieved until 20 years after treatment or even longer.

To relate cancer detection and induction to benefit and risk, it is necessary to consider outcomes both with and without screening. Thus the benefit of screening is not the proportion of those with screen detected cancers who survive a given period, but the difference between that proportion and the

corresponding proportion who would have been predicted to survive if they had been in a comparable unscreened population.

Thus one possible measurement of Benefit/Risk may be taken to be:

$$\text{Benefit/Risk} = \frac{\text{Detections x } (A - B)}{\text{Inductions x } M}$$

Where: A = % survival of screen detected cases, B = % survival of symptomatically detected cases and M = % mortality of symptomatically detected cases. M is defined here in terms of symptomatic detection because it must be assumed at present that the majority of induced cancers will appear in women over the age of 64 who do not refer themselves for screening. If screening of older age groups in future years could be assumed, the mortality of screen-detected cancers would replace that for cancers detected symptomatically.

5.1 Nottingham Prognostic Indicator (NPI)

Of the various sources of data to be considered, that based on the NPI appears to be the most firmly based, and the easiest to interpret and apply. The NPI is calculated as (0.2 x size in cm) + Stage + Grade. The lower the NPI, the better the prognosis. It was first derived empirically from observation and case records, and subsequently verified in a study of 1662 further cases.

The introduction of breast screening leads to the detection of smaller cancers which have a lower NPI value and hence a better chance of long-term survival. Table IV summarises the 15-year survival for different groups of women. The proportion of women presenting in each group before screening is taken from a symptomatic clinic, where as the screening data is based upon a large-scale survey of screen-detected cancers in the Northern and Yorkshire Region of England. (The 15-year survival of an age-matched population of women without breast cancer was 83%.)

Table IV **Nottingham Prognostic Indicator Data**

NPI	15-Year Survival (%)		Proportion of Women Presenting	
	Actual	Age Corrected	Before Screening	After Screening
<3.4	80	96	29	76
3.4-5.4	42	51	54	20
>5.4	13	16	17	4

5.2 Benefit/Risk Ratio

The benefit risk ratio may be calculated using the above equation. Table V is a summary of the ratio of lives saved to the possible fatal cancers induced.

Table V **Benefit/Risk Ratio (Lives Saved/Possible Fatal Cancers Induced)**

Age Band	Single View	Two Views	Highest Dose
50-54	105	62	11
55-59	123	73	13
60-64	188	110	20

6. Discussion

Justification is a fundamental concept in radiation protection legislation and in radiology. A practice is justified when it is beneficial and the benefit can be shown to exceed the associated radiation risk. Justification for a medical radiation procedure can properly be considered in terms of the average dose to all patients, without the need to allow for higher doses that may be received by sub-groups. Nevertheless it would provide added reassurance if it could be shown that benefit exceeded risk for all sub-groups or even for all individuals in a screening programme

In attempting to convert from detection/induction to benefit/risk, data from a variety of sources may be used. Of these data sources, those based upon the NPI may be the best for this purpose. The NPI is derived from parameters that are relatively easy to determine, and its relationship to survival has been established. Survival at 15 years is a much better basis than the 5 years survival widely used for other cancers.

7. Conclusions

For the NHS BSP as it is at present, there appears to be an ample margin of benefit over risk. This statement applies on the basis of the average MGD per woman, i.e. on a population dose basis. Radiological Justification can properly be based on this. At a dose level exceeded by only 0.1% of women screened this remains true. Newer designs of X-ray equipment should lead to further improvements in this position.

Thus, despite all the uncertainties and shortcomings of present information, it does appear that in the NHS BSP radiation hazards if they exist are quite small compared to the benefits. In these terms, the NHS BSP achieves radiological justification. Nevertheless, it remains essential that radiographic image quality, with its implications for cancer detection rates, and radiation dose levels continue to be closely monitored in the NHS BSP and in other breast screening programmes.

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Interventional

Experimental determination of blurring in X-ray fluoroscopy Last Image Hold due to patient movement and its repercussion to patient doses.

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Abstract

Significant dose reduction can be achieved in fluoroscopy and interventional radiology by using the last image hold (LIH). This feature in modern digital fluoroscopy x-ray units usually works with frame or temporal averaging techniques to reduce noise. This image quality works quite well for objects without motion but it could be a serious limitation in presence of motion blur. With an in-house developed robotic device, authors have experimentally determined the image quality degradation introduced by normal physiological movements (i.e., respiratory and cardiac pulse movements). FAXIL test objects TO.10 and 18FG from Leeds University have been used for spatial resolution limit and threshold contrast detail detectability. Seven X-ray equipments with last image hold features from three different manufacturers were analysed. Although results show that motion blur affects LIH in different extend depending on equipment, magnification, entrance dose and detail size, it can be estimated that, on average for all equipments and analysed conditions, represents 30% degradation in image quality parameters in comparison with static images.

1. Introduction

One of the most effective ways for reducing patient doses in fluoroscopy and in interventional radiology fluoroscopy guide procedures is to minimise fluoroscopy time. For that, Last Image Hold (LIH), is a powerful tool. The last image acquired is presented continuously on the monitor until fluoroscopy is once again activated. Meanwhile, radiologists could decide about the diagnosis and further actions to be taken. In the case of an image sequence, the temporal filtering properties of the human visual system reduces perceived noise. In the case of a single constant image (such as LIH) this mechanism does not work and the image looks noisier and low contrast details disappears [1]. For that reason, it is well known that motion affects LIH and in principle it is contradictory to improve the SNR by summation frames or by temporal filtering and at the same time refrain from motion blurring for the same image. There have been some perception studies [2] on motion blurring in x-ray fluoroscopy, but in our knowledge there is not any experimental publication on motion blurring in LIH fluoroscopy. In addition, there are different possibilities to reduce system noise and manufacturers usually do not provide enough information about their designs, among them, summation of 2 frames accumulated in the digital memory, summation of 4 frames in the same way, use of recursive filters with different k factors (weight factors) or use of movement detection circuits [3].

Authors have developed a computer controlled device able to reproduce patient motions and in which it is possible to insert different types of test objects to evaluate image quality in the presence of motion. In this paper, using this device an experimental determination of the degradation of the spatial resolution and low contrast detail perception caused by patient and organ motion is presented for some X-ray equipment with Last Image Hold fluoroscopy.

2. Material and method.

We have designed and constructed a prototype of 2-D motor controlled phantoms with the preliminary goal of simulating clinical situations in which patient movement could be a cause of image degradation or rejection. PAtient MOvement Simulation Test Object (PAMOSITO) was constructed with modular parts to use different mobile test objects and static structures (See [4] for a first PAMOSITO design and applications] The system allows programming different cycles of movement along two axes (x and z). PAMOSITO features two step motors for the z axis with a 50 mm range to simulate the patient respiratory movement and small displacements in X-ray oblique projections. The test object can be moved along the x axis by means of a linear motor with a 145 mm range. The linear motor by Linmot© (Sulzer Electronics AG) allows 500 mm/s of maximum velocity (in increments of 190 mm/s) and 1000 mm/s^2 (in increments of 238 mm/s^2) and is a direct linear drive with integrated position sensing. Those excellent dynamic properties make it possible to simulate very close cardiac pulses or quick involuntary movements.

A layer of 2 mm of copper was used to simulate the patient absorption. The test objects employed for the image quality evaluations were TOR(TO.10) and 18FG for fluoroscopy, from FAXIL [University of Leeds, UK]. The evaluation methodology followed the FAXIL recommended viewing protocol [5]. Three observers scored images for low contrast detectable discs and for high contrast spatial resolution limit. Spatial resolution grid was placed 45° respect the x-motion axis.

PAMOSITO with TO.10 and 18FG test objects was used with the motion curve presented in figure 1, which corresponds to a quiet breathing plus a normal cardiac pulse. This type of motion closely mimic a clinical situation with a sedated patient and it does not affect continuos fluoroscopy. In fact, no significant differences were observed in the fluoroscopy images with this motion curve between the static test object image and the corresponding motion test object images, for all X-ray systems studied. Phantom entrance doses were measured with a RADCAL 2025 external ionising chamber. Doses were normalised at 50 cm phantom entrance surface. Seven different X-ray installations with fluoroscopy and LIH in clinical use for different specialities (vascular, digestive, neurorradiology, and multipurpose systems) were studied. X-ray units were: Toshiba Max1000 (2 units), Toshiba KX080G, Toshiba KXO SDF, Siemens Digitron, Philips BV300 and Philips Omnidiagnost. Image systems admit different magnification, so that images were evaluated for 23 cm, 17 cm and 15 cm fields.

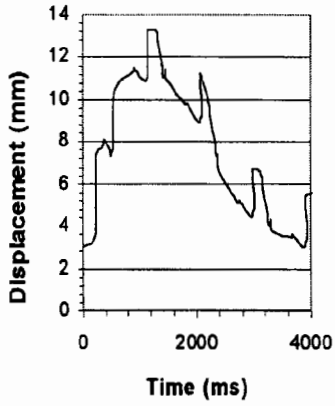

Figure 1: Motion curve loaded into the electronics of PAMOSITO representing a quiet breathing plus a cardiac pulse

3. Results

Comparative results for high contrast spatial resolution limit in three situations (continuous fluoroscopy with the static phantom, LIH with the static phantom and LIH with the curve motion of figure 1) are shown in Table I for different equipments and for different magnifications. As examples of Contrast Threshold Detail Curve results Figure 2 to 5 are presented for two different equipments and two different magnifications.

TABLE I. Reduction of Spatial resolution limit in lp/mm for Last Image Hold with and without patient motion.

	FIELD 23 cm			FIELD 17 cm			FIELD 15 cm		
X-ray equipment	Fluoro No motion	LIH No motion	LIH Motion	Fluoro No motion	LIH No motion	LIH Motion	Fluoro No motion	LIH No motion	LIH Motion
Toshiba KX080G	2.0	1.8	1.4	2.5	2.5	2.0	3.1	3.1	2.2
Toshiba XKO SDF	1.4	1.4	1.1	1.8	1.8	1.4	2.5	2.5	1.8
Toshiba Max1000 (room1)	1.8	1.8	1.4	2.2	2.0	1.4	2.8	2.5	1.6
Toshiba Max1000 (room 2)	1.4	1.4	0.9	2.0	2.0	1.2	2.8	2.8	2.0
Siemens Digitron	1.0	1.0	0.8	1.2	1.1	0.9	18	1.6	1.1
Philips BV300	1.6	1.4	1.1	2.0	2.0	1.8	–	–	–
Philips Omnidiagnost	1.2	1.2	0.9	2.0	2.0	1.1	2.5	2.5	1.4

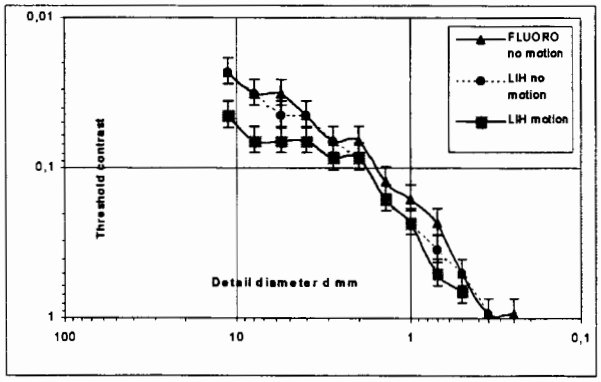

Figure 2: TCDD curve for LIH with and without motion.
Philips Omnidiagnost - Field 23 cm– 71 kV – 14,9 mGy/min

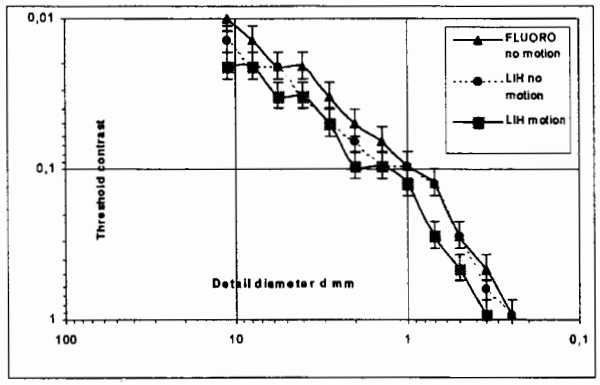

Figure 3: TCDD curve for LIH with and without motion.
Philips Omnidiagnost - Field 17 cm– 74 kV – 25,1 mGy/min

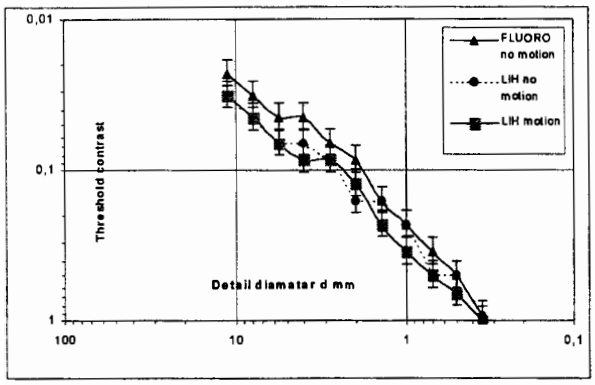

Figure 4: TCDD curve for LIH with and without motion.
Toshiba Max 1000 - Field 23 cm– 71 kV – 9,8 mGy/min

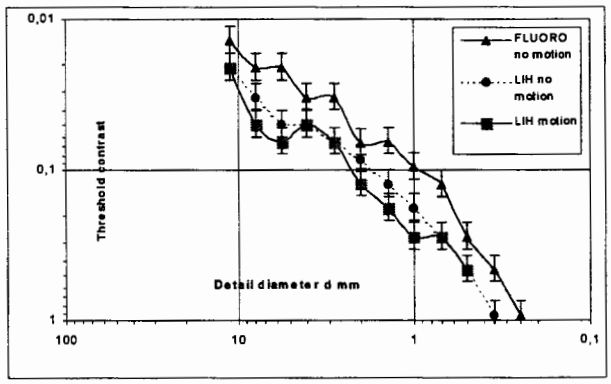

Figure 5: TCDD curve for LIH with and without motion.
Toshiba Max 1000 - Field 17 cm– 75 kV – 16,8 mGy/min

4. Discussion

Note from table I that in the case of no motion spatial resolution is for most situations not affected (on average for all equipments and magnification, the spatial resolution loss can be estimated in 3,5%). This was expected since LIH does not introduce changes in the spatial resolution properties of the system and as mentioned before manufacturers introduce some noise reduction techniques so that noise is not usually a limitation for the spatial resolution limit. However motion blurring affect the LIH significantly and it is more important in magnification modes. On average for all equipments, the loss of spatial resolution is 26,5% (field 23 cm), 28,5% (magnification mode; field 17 cm) and 35% (magnification mode; field 15 cm) respect the corresponding fluoroscopy image. This fact must be known by interventional radiologists since magnification usually requires higher surface entrance patient doses. For example the phantom entrance dose for the Philips Omnidiagnost equipment (last row in table I) was 14,9 mGy/min (field 23 cm), 25,1 mGy/min (field 17 cm) and 39,4 mGy/min (field 15 cm). Note in last row of table I that the improvement of spatial resolution achieved by using the magnification is lost by the LIH with patient motion.

As stated in the introduction more significant losses are observed both for LIH with static objects and LIH with motion objects for Low Contrast Detail sensitivity. Here, we have observed differences depending not only on magnification (compare figure 3 and figure 5 respect figure 2 and figure 4) but on the manufacturer equipment and model (which likely could be explained by use of different temporal filters or number of added frames to built the last image hold). The equipment for figures 2 and 3 shows little degradation when using LIH in static object and an important extra degradation for LIH in moving objects, on the contrary, the equipment for figures 4 and 5 shows an important degradation for LIH and static objects and a little extra degradation for LIH and moving objects. On average for all equipments, magnifications and detail sizes the loss in contrast detail sensitivity for LIH and moving objects is 30% respect to the corresponding fluoroscopy images.

5. Conclusions

Although results show that motion blur affects LIH in different extend depending on equipment, magnification, entrance dose and detail size, it can be estimated that, on average for all equipments and analysed conditions, represents 30% degradation in image quality parameters. Degradation is more important in magnification modes so that radiologists should be known this fact to optimise their protocols. Manufacturers should be encouraged to improve image quality of LIH both for static and motion structures since it use is essential for patient dose reductions.

6. Acknowledgements

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COMPARACION ENTRE TIEMPO DE FLUOROSCOPIA Y DOSIS EN PACIENTES SOMETIDOS A ABLACIONES POR CATETER SEGUN DIAGNOSTICO. FUNDAMENTOS PARA IMPLEMENTAR UN PROGRAMA DE GARANTIA DE CALIDAD

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ABSTRACT

Radiofrequency Cardiac Catheter Ablation is an Interventional Radiology procedure of great complexity because of the cardiologist needs of a simultaneous evaluation of fluoroscopic images and electrophysiologic information.. Therefore, the procedure typically involves extended fluoroscopic time that may cause radiation-skin injures to patients. Skin doses depend on many factors: equipment design features and its properly use, cardiologist practice, fluoroscopic time, irradiated areas, application of radiation protection recommendations, etc. We evaluate fluoroscopic time in relation to pathology and we estimate skin doses on 233 procedures at the Electrophysiology Laboratory in Casa de Galicia, Montevideo, Uruguay. Significant differences among the medians of fluoroscopic time were found in those procedures depending on diagnoses and results. Higher fluoroscopic time was found in flutter and auricular tachycardia(median was 83 minutes, p=0.0001). In successful procedures (almost 90%), median skin doses was 2.0 Grays(p=0.0001). On the basis of records information , the standard operating procedure and the clinical protocol, expanding close cooperation between the cardiologists and the experts in Radiation Protection will secure the establishment of an Assurance Quality Program.

INTRODUCCION

La ablación por catéter utilizando radiofrecuencia(AC) es la primera opción terapéutica para un numeroso grupo de pacientes con taquiarritmias. La mayoría de las taquicardias de significación clínica se deben al mecanismo de reentrada, es decir, a la existencia en el corazón de un circuito anatómica y electrofisiológicamente definido que depende para su funcionamiento de una zona crítica. Identificando el circuito mediante un estudio electrofisiológico(EEF) y aplicando radiofrecuencia(AC) en su zona crítica, puede eliminarse la arritmia y curar al paciente. La ubicación de los catéteres se realiza a partir de imágenes fluoroscópicas. La complejidad del procedimiento hace que, en algunos casos, las dosis recibidas por los pacientes pueden producir efectos deterministicos en su piel[1].Uruguay no tiene un Programa Nacional de Protección Radiológica(PR) y el currículum de la especialidad Cardiología no tiene horas asignadas a la formación en PR. Esto motivó el inicio a partir de agosto del año 2000, de un Programa de Educación en PR en Cardiología Intervencionista. Al iniciarse la etapa de evaluación de los procedimientos, los profesionales del Laboratorio de Electrofisiología Cardíaca de Casa de Galicia son ampliamente receptivos a la implementación de un Programa de Garantía de Calidad [2].
Con el fin de evaluar indicadores de posibles efectos deterministicos en la piel de los pacientes sometidos a AC, el presente trabajo tiene como objetivo determinar los tiempos

de fluoroscopía (*t*)y estimar las dosis en piel de pacientes(D)en función del diagnóstico que justifica el procedimiento.

MATERIAL Y METODOS

El trabajo se realizó en el Laboratorio de Electrofisiología de Casa de Galicia sobre un total de 383 procedimientos en el período diciembre de 1992 a octubre de 2000.Se consideraron únicamente aquellos procedimientos realizados una única vez por sesión (n = 283) en los que se aplicaron los siguientes criterios de exclusión: carencia o dudas en los datos de *t* (n = 22), diagnósticos poco concluyentes (n = 10) o más de uno (n = 17) en el EEF, con lo que la población definitiva queda reducida a 233 AC en 218 pacientes, de las cuales 12 (5.2%) son reintervenciones en procedimientos independientes. Los diagnósticos del EEF fueron clasificados en 4 grupos (Tabla I).

Tabla I. Agrupación de Diagnósticos en el EEF

Diagnóstico	N (%)
Reentrada Nodal (RN)	103 (44.2)
Vías Accesorias (VA)	66 (28.3)
Flutter y Taquicardias Auriculares (FT)	37 (15.9)
Otros diagnósticos (*)	27 (11.6)

(*) Fibrilación auricular crónica(n=17), Fibrilación auricular paroxística (n = 7)yTaquicardias ventriculares (n=3).

Los tiempos de fluoroscopía fueron registrados sistemáticamente en el período junto a características básicas de los pacientes de interés para este estudio registradas en las historias clínicas y en la base de datos del Servicio de Electrofisiología (Tabla II).

Tabla II. Características básicas de los pacientes sometidos a AC

Diagnóstico	RN	VA	FT	Otros
N	103	66	37	27
Hombres (%)	23 (22.3)	37 (56.1)	20 (54.1)	22 (81.5)
Edad +/- 1ds (años)	49.7 +/- 18	37.1 +/- 18	56.7 +/- 14	58.8 +/- 10
Talla +/- 1ds (cm)	164 +/- 8	168 +/- 13	169 +/- 10	173 +/- 11
Peso +/- 1ds (Kg)	67 +/- 16	75 +/- 18	78 +/- 12	86 +/- 21

El equipo de fluoroscopía utilizado en todas las AC fue Siemens Elema modelo Angioskop D (año 1991), no tiene radioscopía pulsada ni mantiene la última imagen y careció de controles de calidad.

Todas las AC fueron realizadas por el mismo equipo de médicos electrofisiólogos, y se utilizaron los siguientes protocolos estandarizados: a) clínico, que comprende la inserción como mínimo de 4 catéteres: uno en seno coronario por vía subclavia y los restantes en aurícula y ventrículo derechos por vía femoral. El catéter de ablación siempre dispuso de un electrodo distal de 4 mm de superficie, con y sin control de temperatura, conectado a un generador de radiofrecuencia Medtronic-Cardiorrythm modelo Atakr. b)radiológico, inserción del catéter en seno coronario con proyecciones AP y OAI en un *t* promedio de un minuto. Inserción del resto de los catéteres, procedimientos diagnósticos y terapéuticos con

proyecciones OAD (60% de *t*) y OAI (40% de *t)*. Durante toda la práctica: diámetro de entrada del II es 23 cm, máxima distancia foco-piel y mínima distancia intensificador-piel. Debido a que, no se dispone de instrumental, se optó por el método que sigue para estimar D. Las constantes para la estimación de D fueron proporcionadas por la empresa CONATEL, que realiza el Servicio Técnico del equipo radiológico. De acuerdo al equipo radiológico utilizado y los protocolos arriba señalados, se aplicó la siguiente:

D (Gy) = 1.35x(Rendimiento)x (m A)x tiempo de Fluoroscopía

Donde: 1.35 es el factor de retrodispersión, m A es el promedio estimado a partir del equipo y del protocolo practicado[3][4]. Se aplican los factores de equivalencia entre unidades de medida y se realiza la corrección de la distancia para obtener el rendimiento a la entrada de la piel. Este método sobrestima la dosis en piel [3][4].

Se consideraron finalmente los resultados de la AC de acuerdo a los siguientes criterios clínicos:

a) Éxito. Eliminación de la taquicardia por modificación o eliminación de la conducción en la vía lenta(en RN), por eliminación del o las VA, y en el flutter auricular la demostración de bloqueo bidireccional a nivel del istmo cavo-tricuspídeo.
b) Éxito Parcial. No se cumplen totalmente los criterios de éxito aunque los circuitos de taquicardia son modificados. Solamente la evolución clínica podrá definir el éxito total.
c) Falla. El procedimiento no cumple con ninguno de los objetivos.

METODOS ESTADISTICOS

Las variables centrales del estudio son estimadores de la radiación recibida por los pacientes sometidos a AC: los *t* registrados y una estimación de D durante las AC a través de la ecuación lineal descrita en métodos. Las variables de agrupamiento y comparación son los diagnósticos establecidos en el EEF y los resultados de la AC. Las distribuciones de ambos estimadores según diagnósticos difirieron significativamente de la normalidad según el test de Shapiro-Wilk, solamente se comportaron como normales las pequeñas distribuciones (éxito parcial y falla) por lo cual las comparaciones de *t* y de D se realizan a través de las pruebas no paramétricas de Kruskall-Wallis y Mann-Whitney. Las comparaciones de proporciones de éxito según los diagnósticos se establecieron por medio de chi cuadrado, 1 grado de libertad. En todos los casos alfa = 0.05. Los datos fueron procesados en EPI INFO 6.04 B y Prophet V5.0.

RESULTADOS

Las medianas de *t* (83 min) y D estimada (5.0 Gy) para el diagnóstico FT fueron significativamente mayores que para los otros diagnósticos, los que no mostraron diferencias significativas entre sí (Tabla 3 y Figura 1).

Tabla III. Tiempos de Fluoroscopia(*t* en minutos) y Dosis (D en Gy) según diagnósticos

Diagnóstico	RN	VA	FT	Otros
t Media +/- 1ds	36 +/- 25	52 +/- 43	91 +/- 50	42 +/- 35
t Mediana	28	42	83	36
D Media +/- 1ds	2.1 +/- 1.5	3.1 +/-2.6	5.5 +/- 2.9	2.5 +/- 2.1
D Mediana	1.7	2.5	5.0	2.2

Las medianas de *t* (33 min) y D estimada (2.0 Gy) para el resultado éxito fueron significativamente menores que para los otros resultados, los que tampoco mostraron diferencias significativas entre sí (Tabla IV y Figura 2)

Tabla IV. Tiempos de Fluoroscopia (*t* en minutos) y Dosis (D en Gy) según resultados de AC

Resultado	Exito	Éxito Parcial	Fallo
N (%)	207 (88.8)	8 (3.4)	18 (7.7)
t Media +/- 1ds	42 +/- 31	107 +/- 48	116 +/- 51
t Mediana(min)	33	107.5	120
D Media +/- 1ds(Gy)	2.5 +/-1.9	6.9 +/- 2.9	6.9 +/-3.0
D Mediana(Gy)	2.0	6.4	7.2

La proporción de éxitos en FT, 24/37 (64.9%) es significativamente menor que RN(97.1%), p = 0.00001 y que VA(90.9%), p = 0.001, pero no con otros, 23/27 (85.2%), p = 0.07.

DISCUSION

Si bien existe bibliografía de D en AC, no es habitual vincular D y *t* a los diagnósticos que justifican los procedimientos y sus resultados. Al tratarse de los mismos médicos electrofisiólogos, equipos de fluoroscopia y de radiofrecuencia, catéteres de ablación y protocolos clínicos y radiológicos, los diagnósticos y resultados de las AC determinan *t* y D, aunque nuestro cálculo de D está sujeto a error y tiende a la sobreestimación. En FT, *t* y D son elevados porque es una patología compleja, los catéteres tienen una superficie pequeña y el número de casos(15.9%) es bajo para modificar la curva de aprendizaje. La mediana de *t* en los procedimientos exitosos(casi 90%) es 33 minutos y aceptable para nuestras condiciones. Al considerar FT, el éxito es significativamente menor, lo que explica que sea el diagnóstico con mayor *t* y D. Clínicamente, *t* podría optimizarse utilizando catéter de superficie mayor a 4 mm; físicamente, *t* puede disminuirse con equipo de fluoroscopía pulsada, que sostenga la última imagen y con equipo biplano. D puede disminuirse aplicando un Programa de Garantía de Calidad y con un equipo de RX con otras características técnicas. Pese al error de nuestro cálculo de D, los pacientes sometidos a AC por FT, pueden alcanzar fácilmente el umbral de dosis para efectos determinísticos en piel [5].Es necesario medir D con protocolos establecidos e instrumental, para evaluar estos

efectos y probabilidades de estocásticos. Dada la curva de aprendizaje de los médicos electrofisiólogos es difícil que cambie la diferencia de *t* entre FT y los demás diagnósticos.

CONCLUSIONES

El tiempo de fluoroscopía y las dosis están determinados por el diagnóstico. Al evaluarse los elementos clínicos y físicos de este Laboratorio, se fundamenta el establecimiento de un Programa de Garantía de Calidad que será referencia en nuestro medio.

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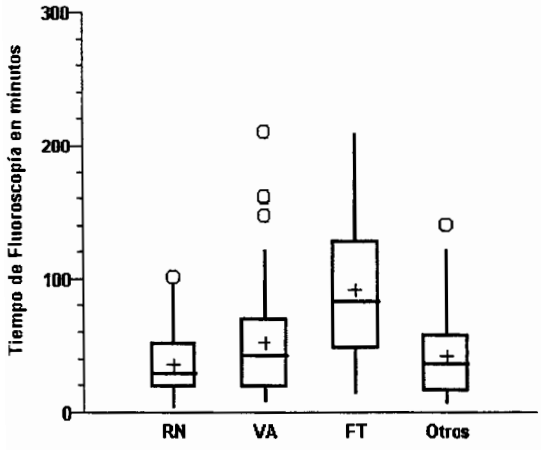
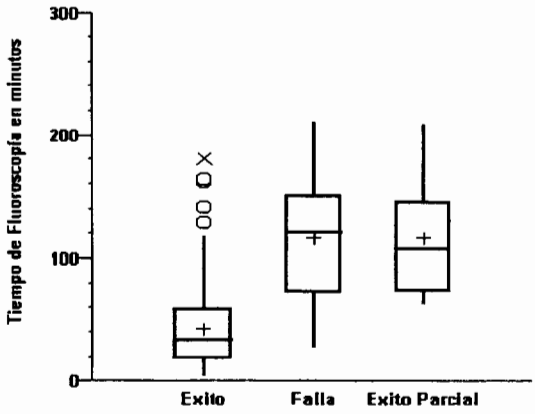


Figura 1. Comparaciones de tiempos de fluoroscopia en 233 ablaciones por catéter de radiofrecuencia según diagnósticos en un servicio de Electrofisiología de Montevideo, Uruguay, entre 1992 y 2000.
El tiempo de FT es significativamente mayor que el del resto de los diagnósticos (kruskall-wallis, p = 0.0001) quienes no mostraron diferencias significativas entre sí.



RN : reentrada nodal (n = 103), VA: vías accesorias (n = 66), FT: flutter y taquicardias auriculares (n = 37) y Otros (n = 27.

Figura 2. Comparaciones de tiempos de fluoroscopia en 233 ablaciones por catéter de radiofrecuencia según resultados obtenidos en un servicio de Electrofisiología de Montevideo, Uruguay, entre 1992 y 2000. El tiempo de éxito es significativamente menor que el de los otros resultados (kruskall-wallis, p = 0.0001) quienes no mostraron diferencias significativas entre sí.

Éxito (n= 207), éxito parcial (n = 8) y falla (n = 18).

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PROPUESTA DE NIVELES RESTRICCIÓN DE DOSIS PARA LA EXPOSICIÓN OCUPACIONAL EN LAS PRÁCTICAS MÉDICAS

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ABSTRACTS

A study was carried out in order to propose restriction levels for occupational exposures in Nuclear Medicine and Teletherapy. The initial data were the annual doses of occupational exposed workers reported by external dosimetry of 23 institutions since 1990 to 1999, which were analyzed by statistical processing to obtain the variation ranges of this magnitude. Dose values corresponding to the 75-percentil were then considered in this study. Simultaneously, a model of the exposure scenarios was used for the estimation of the annual effective doses, this estimation was supported with measurements of dose rates carried out in the institutions. The restriction levels were obtained by multiplying the sum of the annual doses (normal and potential) by a reserve coefficient defined in the present work. The determined restriction levels are in the range of those obtained by other similar studies.

I. INTRODUCCIÓN

La Comisión Internacional de Protección Radiológica (CIPR) ha recomendado el establecimiento de las restricciones de dosis para la exposición ocupacional [1], como base para la aplicación del principio de optimización de la protección radiológica [2]. Su selección se hace necesaria e indispensable para garantizar que las dosis recibidas por los trabajadores no excederán los valores que exigen las buenas prácticas, para las cuales estos constituyen un requerimiento mínimo.

En el presente trabajo se presentan los resultados de un estudio realizado para establecer niveles de restricción de dosis ocupacional en las prácticas de medicina nuclear y teleterapia en el ámbito nacional. Los datos de partida fueron las dosis individuales anuales de trabajadores ocupacionalmente expuestos reportadas por dosimetría externa de 23 instituciones durante los años 1990-1999, con una estadística de casi 2500 valores de dosis, a los cuales se les realizó un procesamiento estadístico para la obtención de los rangos de variación de esta magnitud, siendo considerados los valores correspondientes entre el 25 y 75-percentil.

La metodología empleada consistió en una comparación de los niveles de dosis, obtenidos por práctica, de dos fuentes de información diferentes: una, el valor del 75-percentil correspondiente a la distribución de las dosis por dosimetría externa; y otra, el valor de dosis como resultado de la modelación por cálculo de los escenarios de irradiación que se complementó con mediciones de tasas de dosis realizadas en las instituciones. Con la determinación de los factores de reserva por práctica se tuvo en cuenta las incertidumbres de las exposiciones futuras.

II. CARACTERIZACIÓN RADIOLÓGICA DE LAS PRÁCTICAS

La caracterización estuvo conformada por la determinación de los rangos de variación de las dosis individuales anuales y la estimación de los valores de riesgo para cada una de las prácticas identificadas. La evaluación de los rangos de variación de las dosis individuales se realizó mediante el procesamiento de los datos de la dosimetría individual en un período de diez años y la modelación de los escenarios de exposición. Todo esto con la finalidad de intercomparar los resultados obtenidos para la determinación de un valor de dosis optimizado que reflejara lo mejor posible las condiciones de trabajo en las instituciones, y llegar a una conclusión en cuanto a las dosis en condiciones normales. En la Tabla I se muestran los datos de partida utilizados en el análisis.

Tabla I. Características generales de las prácticas

Práctica	Fuente	Actividad	Personas
Medicina Nuclear	Generadores Mo-Tc99m, Tl^{201}, P^{32}, I^{131}	Unidades de μCi hasta decenas de mCi	1957
Teleterapia	Cabezales de Co-60 y fuentes patrones	Hasta miles de Ci	489

En el caso de la determinación de los rangos de dosis individuales basados en los datos del servicio de dosimetría externa estos fueron agrupados por práctica.

Para la modelación de los escenarios de exposición, además de emplearse las tasas de dosis de los resultados del monitoreo de áreas in-situ, se realizaron encuestas en las instituciones para determinar: las posiciones del personal durante las operaciones, frecuencia de permanencia en estas y los tiempos de exposición. En la práctica de medicina nuclear se tuvieron en cuenta las siguientes operaciones: recepción, preparación y administración de radiofármacos y medición de pacientes. En teleterapia, las operaciones evaluadas fueron: posicionamiento e irradiación del paciente. Las operaciones contempladas y las dosis asociadas, tanto por dosimetría externa como por cálculo se muestran en la Tabla II. Los valores extremos de los rangos de dosis por dosimetría externa están determinados por el primer y tercer cuartiles. En el caso de los de modelación de escenarios, por los valores mínimos y máximos obtenidos por cálculo en las instituciones de medicina nuclear.

Tabla II. Desglose de las dosis ocupacionales recibidas en las diferentes etapas por práctica

Medicina Nuclear		
Operación realizada	**Modelación de escenarios**	**Dosimetría externa**
	Dosis efectiva anual [mSv]	
Recepción del material radiactivo	0.04 - 0.10	**0.71 – 2.50**
Elución de generadores	0.01 - 0.10	
Preparación de los radiofármacos	0.20 - 0.60	
Preparación de las dosis de radiofármacos	0.50 - 0.90	
Administración de las dosis	0.20 - 0.90	
Medición de pacientes	1.00 - 1.80	
Dosis total	**1.95 - 4.40**	
Teleterapia		
Posicionamiento del paciente	0.20 - 0.50	**0.71-2.52**
Irradiación del paciente	1.00 - 1.50	
Dosis total	**1.20 - 2.00**	

III. EVALUACIÓN DEL RIESGO

Los riesgos de exposiciones potenciales se evaluaron a partir de los datos de dosis estimados para los posibles sucesos postulados en cada una de las prácticas a caracterizar. Los sucesos tenidos en cuenta fueron aquellos que condujeran a un incidente o incidente importante según la escala establecida en el país [3]. La probabilidad de los sucesos relacionados con instalaciones de irradiación se estimó sobre la base fundamentalmente de la experiencia y los datos estadísticos reportados internacionalmente [4], a partir de los árboles de fallas diseñados para ellas. Los sucesos vinculados con fuentes no selladas se limitan a derrames y daños a su contención. En la Tabla III se muestran los sucesos evaluados, las probabilidades de ocurrencia estimadas [4, 5], así como los valores de dosis involucrados. El riesgo

de contraer cáncer mortal se calculó como el producto de la probabilidad (P) y la dosis efectiva (E) por el coeficiente de riesgo para trabajadores de $4.0 \cdot 10^{-2}$ Sv^{-1} que establece la CIPR [1].

Tabla III. Datos considerados para la estimación del riesgo

Suceso	Probabilidad	Dosis (mSv)
Medicina Nuclear		
Derrame insignificante	$7.7x10^{-2}$	~ 0.1
Derrame mayor	$3.8x10^{-3}$	~ (1.0 – 100.0)
Radioterapia		
Atascamiento de la fuente durante la irradiación	$1.0x10^{-3}$	< 10.0
Entrada inadvertida de TOE a la sala	$1.0x10^{-4}$	~ (10.0 – 1000.0)

Determinación del factor de reserva

El factor de reserva es el margen dejado para posibles exposiciones adicionales futuras. Expresa el cociente de la suma de las dosis presentes y futuras entre las presentes. Por otro lado, para las prácticas identificadas, éste varía en dependencia de los escenarios de exposición, condiciones y proyecciones de trabajo futuro de cada una de ellas. En la práctica de medicina nuclear se estimó que las exposiciones futuras aportan el 50% de las presentes por la gran incidencia del factor humano y el aumento de las actividades empleadas, pues se espera mayor aplicabilidad de la terapia metabólica y la inmunogammagrafía. En teleterapia, las exposiciones futuras aportan sólo un 20% porque las condiciones de irradiación prácticamente no varían y en nuestro país estos equipos están explotados al máximo de sus capacidades.

Selección de las restricciones de dosis

De los rangos de dosis se consideró el 75-percentil: 2.50, para medicina nuclear; 2.52, para radioterapia. A estos se les sumó la multiplicación de la dosis potencial por su probabilidad de ocurrencia. Finalmente, el valor de la restricción de dosis se obtiene por la multiplicación del factor de reserva por la dosis total.

IV. RESULTADOS Y DISCUSIÓN

Como resultado se obtuvo una metodología para la obtención de los niveles de restricción ocupacionales muy flexible, siendo su aplicación extensiva a otros tipos de prácticas. El algoritmo se muestra en la Figura 1.

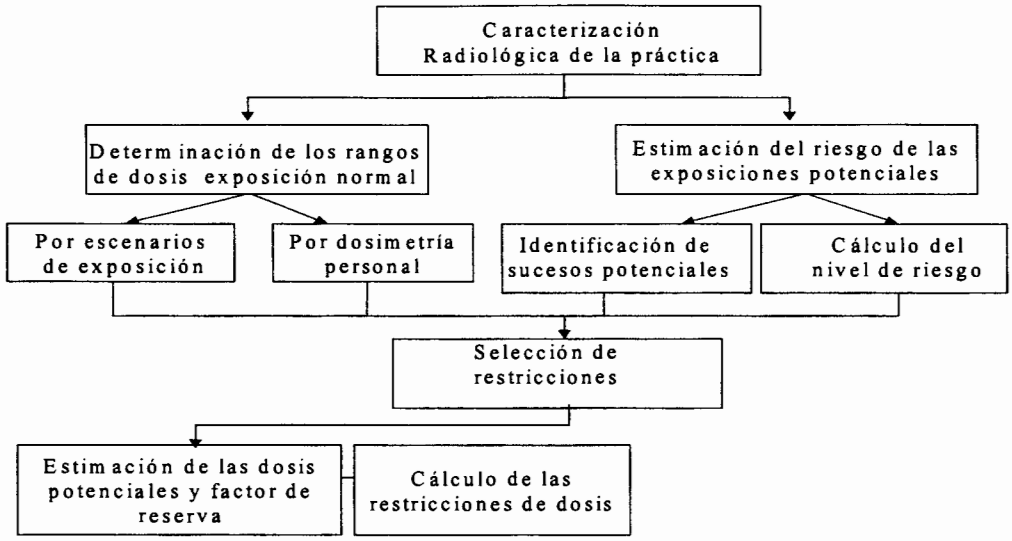

Figura 1. Algoritmo empleado en la selección de los niveles de restricción de dosis ocupacional.

Los rangos de dosis determinados por la dosimetría individual están en el rango de los estimados por modelación, ello evidencia que de forma general, en estas prácticas se cumplen los requisitos establecidos para las buenas prácticas.

En la Tabla IV se muestran la dosis 75-percentil, dosis potencial, factores de reserva y niveles de restricción de dosis para las prácticas de medicina nuclear y teleterapia. La estimación del riesgo, aún bajo presupuestos y cálculos conservadores, arrojó los resultados esperados: los valores de dosis obtenidos por multiplicación de las dosis potenciales por sus probabilidades de ocurrencia son irrelevantes comparadas con las dosis por exposición normal.

La dosis 75-percentil de la distribución de las dosis anuales reportadas por dosimetría externa se tomó como punto de partida en la determinación de los niveles de restricción de dosis por

Tabla IV. Rangos de dosis y valores de riesgo obtenidos

Práctica	**Dosis 75-percentil (mSv)**	**Probabilidad de ocurrencia por dosis esperadas en las exposiciones potenciales (mSv)**	**Factor de reserva F**	**Restricción de dosis (mSv)**
Medicina nuclear	2.50	$\sim (8x10^{-3}\text{-}4x10^{-1})$	1.5	4
Teleterapia	2.52	$\sim (1x10^{-2} - 1x10^{-1})$	1.2	3

Los niveles de restricción de dosis propuestos en este trabajo están en el orden de los aplicados internacionalmente, no obstante como práctica estos deben ser sujetos una revisión periódica o cuando se produzca cambios significativos en las condiciones de exposición ocupacional.

De adoptarse los niveles de restricción de dosis propuestos, sería necesario implementar medidas correctivas, que conlleven a la optimización de las exposiciones ocupacionales, ya que un 11.5 % y un 15.4 % de los trabajadores de las prácticas de medicina nuclear y teleterapia respectivamente reciben dosis por encima de estos niveles.

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PREVENCIÓN DE ERRORES EN UN TRATAMIENTO RADIOTERÁPICO CONTROLADO CON UN SISTEMA DE REGISTRO Y VERIFICACIÓN

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Abstract

Computerized record and verify systems are being used increasingly to improve the precision of radiotherapy treatments. With the introduction of new treatment devices, such as multileaf or asymmetric collimators and virtual wedges, the responsibility to ensure correct treatment has increased.
The purpose of this paper has been to present the method that we are following to prevent some potential radiotherapy errors.

Introducción

En los últimos años se vienen introduciendo en los Servicios de Radioterapia los sistemas de registro y verificación (RVS) que, entre otras cosas, permiten seleccionar datos de irradiación de los pacientes en los modernos aceleradores lineales de electrones (ALE) usados en radioterapia externa [1,4]. Estos sistemas constituyen un medio efectivo de verificar los datos de irradiación programados para el tratamiento de cada paciente, impidiendo aplicarlo si algún dato de la máquina se encuentra fuera de un margen previamente establecido o si no se ha colocado algún accesorio programado (bandeja, cuña, aplicador).
El objetivo de este trabajo es presentar el proceso que seguimos para tratar de evitar errores en los tratamientos radioterápicos, así como llamar la atención sobre algunas dificultades que pueden encontrarse usando los modernos aceleradores dotados de un sistema de colimación que permite definir campos asimétricos y dotados de cuñas virtuales, conectados a un sistema RVS.

Material y Método

En nuestro hospital se dispone de dos ALE (Mevatron KD2 y Primus de Siemens) que están conectados a un sistema de RVS Lantis de Siemens (Sistema de información para redes locales), que, entre otras cosas, permite:

- seleccionar dentro de una lista el paciente que va a recibir tratamiento
- visualizar los datos clínicos y administrativos del paciente
- visualizar un resumen de las notas de configuración y campos de tratamiento a aplicar
- visualizar los parámetros de los campos de tratamiento

- la configuración automática del ALE: parámetros de consola, parámetros geométricos, accesorios y posiciones del colimador
- comprobar que los parámetros prescritos concuerdan con los reales
- registrar los parámetros dosimétricos de los campos sobre los que se ha administrado tratamiento
- configurar y realizar actividades de película portal.

Procedimiento seguido antes de iniciar el tratamiento de un paciente

La dosimetría clínica de cada paciente la realiza un físico o un dosimetrista, y es revisada siempre por un radiofísico.
El radioterapeuta cumplimenta la ficha de cada paciente en presencia del radiofísico y con los datos que éste le suministra relacionados con la colocación y el tratamiento del paciente.
El radioterapeuta introduce los datos de la ficha de tratamiento en el sistema Lantis. En caso de que el tratamiento incluya un campo conformado con multiláminas, el físico introduce en el sistema Lantis la forma del campo.
El radioterapeuta autoriza los campos introducidos en el Lantis para el tratamiento de cada paciente.
Previamente a la primera sesión de tratamiento de cada paciente:
Los ATS/técnicos de la sala de tratamiento comprueban que los datos de la ficha coinciden con los que muestra la pantalla del ordenador para ese paciente, y, en el caso de campos conformados, comprueban que su forma coincide con la que figura en las placas realizadas en el momento de la localización/simulación del tratamiento, dibujando la forma del campo sobre ellas, para su posterior revisión por el radioterapeuta.
El radioterapeuta y el radiofísico comprueban, a su vez, que los datos dosimétricos y de colocación que figuran en la pantalla coinciden con los usados en los cálculos dosimétricos.

Se procede entonces a la colocación del paciente para recibir su primera sesión de tratamiento, en presencia del radioterapeuta y del radiofísico y éstos firman la ficha si todo está conforme.
Semanalmente, el radiofísico y el radioterapeuta, por separado, revisan las fichas de tratamiento y comprueban que coinciden los datos de dosis acumulada en cada campo y número de unidades de monitor para cada campo con los almacenados en el sistema Lantis.

Algunos errores que pueden cometerse/evitarse

A lo largo del tiempo de trabajo con los citados ALE, hemos podido ver que pueden surgir inicialmente algunos errores relacionados con la falta de costumbre de uso de las posibilidades que ofrecen (campos asimétricos, cuñas virtuales).

1º) Relacionadas con la tecnología de los nuevos ALE

En el caso de campos asimétricos se puede cometer un error si se traspasan directamente al sistema Lantis las dimensiones de las cuatro mandíbulas (X1,X2, Y1,Y2) utilizadas en el

planificador y éste no tiene en cuenta el giro del colimador que se vaya a utilizar en el tratamiento.
Este error, que es fácilmente detectable en el posicionamiento del paciente, puede evitarse si previamente se establece una tabla de correspondencia de la posición de cada mandíbula considerada en el planificador, con la de la unidad de tratamiento, en función del ángulo de colimación utilizado. Al cumplimentar la ficha de tratamiento, resulta muy cómodo usar la citada tabla.

Otro posible error puede venir derivado de no estar familiarizados con las cuñas virtuales que se simulan moviendo una de las mandíbulas del ALE. Es preciso tener establecido claramente el modo de controlar cómo se forman las cuñas virtuales, sabiendo, según la orientación de la cuña que figura en los cálculos dosimétricos, qué posición deben ocupar las mandíbulas que delimitan el campo de tratamiento del paciente para que la cuña virtual se genere en la dirección y sentido debidos.
Este posible fallo puede controlarse de forma sencilla, bien fijando una pegatina en las mandíbulas del ALE que indiquen, según la orientación prevista de la cuña, qué mandíbula corresponde a la parte gruesa de la misma (por ejemplo, orientación 1 mandíbula Y1, orientación 2 mandíbula Y2) y comprobar en la primera colocación del paciente para su tratamiento que la ficha está perfectamente cumplimentada en cuanto a la identificación de la orientación de la cuña y ángulo de colimador para que la cuña se genere según se había previsto.

2º) Relacionadas con posibles confusiones de las personas que aplican los tratamientos a diario.

Además de los posibles errores de posicionamiento que se pueden evitar utilizando un sistema que controle los datos de irradiación del paciente mediante ordenador, hemos podido detectar en algún caso, al verificar semanalmente la coincidencia de las sesiones de tratamiento que figuran en la ficha con las que figuran en el sistema Lantis, que se había olvidado de tratar un campo, en un tratamiento con varios campos, o que se había olvidado de anotar en la ficha un tratamiento que sí se había efectuado.
También pueden producirse errores en la suma de las dosis que se van acumulando al cumplimentar la ficha de modo manual.
Estos raros errores, se pueden detectar fácilmente en las revisiones semanales disponiendo de un sistema RVS, no teniendo mayor transcendencia pero su existencia hace pensar que pueden ocurrir, y no ser detectados, en otras unidades que no dispongan de este tipo de sistemas.

También puede ocurrir que se llame a un paciente para que entre a la sala de tratamiento y que sea seleccionado el nombre de otro paciente en la pantalla del ordenador. Si, casualmente, la localización del tratamiento en ambos pacientes y los tamaños y formas de campo son similares, puede ocurrir que no se detecte la equivocación y se trate al paciente con un número erróneo de unidades de monitor, es decir, con una dosis inadecuada. Este error es más fácil que ocurra cuanto más automatizado sea el tratamiento en cuanto a los posibles accesorios que conlleve (bloques, cuñas). Si, por ejemplo, la cuña es virtual,s e

generará según esté programada, pero si la cuña fuera física, debería coincidir para que se pudiera irradiar que la cuña programada para ese paciente coincidiera con la que tenía programada el paciente seleccionado de forma equivocada.
Este error puede verse favorecido por el modo de visualización de los nombres de los pacientes en la pantalla (por ejemplo, tamaño pequeño de las letras) en el momento de seleccionar el paciente, por el hecho de que la persona que aplica el tratamiento rellene la ficha, sin detectar que el número de unidades de monitor de la pantalla no coincide con el que figura en la ficha, ya que no sospecha su confusión.
Este fallo se puede detectar fácilmente porque cuando se selecciona de nuevo el nombre del paciente para su tratamiento, que esta vez sí que corresponde al paciente real, el sistema de RVS avisa de que el paciente ya se ha tratado ese día, pudiéndose entonces realizar las estimaciones de dosis necesarias.

Conclusión

El uso de un sistema de registro y verificación permite evitar un número significativo de errores y detectar otros en los tratamientos radioterápicos. También la introducción de aceleradores lineales de electrones con modernos sistemas de colimación permiten tratamientos más precisos, pero es necesario establecer bien la correspondencia entre los datos usados en el planificador y los introducidos en el sistema RVS para controlar la irradiación de cada paciente.
Es preciso establecer un programa eficaz para controlar que los tratamientos se llevan a cabo según lo programado y para detectar posibles errores. A ello contribuyen en gran medida las revisiones previas a la primera sesión de tratamiento de un paciente y la revisión semanal de la ficha. Una estrecha colaboración entre radioterapeutas, físicos y personas que aplican los tratamientos es de gran importancia, de forma que entre ellos se pueda transmitir la información y sistemática de trabajo de forma clara.

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COMPARACIÓN DE DOS QUÍMICOS DE PROCESADO DIFERENTES PARA MAMOGRAFÍA: REPERCUSIÓN SOBRE LA SENSIBILIDAD DEL SISTEMA PANTALLA-PELÍCULA

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1. Abstract

The main technical objective of screen-film mammography is to reach the best image quality with the lowest dose to the breast. Sensitometric gradient and speed are factors related with both subjects respectively. For a given choice of film, these factors are affected by processing variables. By this reason, manufacturers have developed diferent types of films that are recommended for particular processing conditions.
The purpose of this work is to compare the variations of both sensitometric characteristics of mammographic screen and film systems induced by two different manufactured chemicals: RPX-Omat EX/LO (Kodak) and G139/G334 (Agfa). A comparison of thirteen mammographic films by means of light sensitometry was performed at different processing conditions: 90s/Kodak, 120s/Kodak, 180s/Kodak, 90s/Agfa, 120s/Agfa and 180s/Agfa. Secondly, 99 combinations of screens and films were evaluated by X-ray sensitometry at 120s/Kodak and 120s/Agfa processing. At light sensitometry, variations in processing time led to different modifications in film speed, depending on the chemicals used. At X-Ray sensitometry, Agfa chemicals induced higher values of sensitivity for almost all combinations, while Kodak chemicals gave higher gradient/speed quotient. The results show that dose to patients in mammography and image contrast are highly dependent on the chemicals selected at medium cycle (120s) processing.

2. Introducción

La mamografía es un procedimiento radiológico cuyo uso ha tenido un importante incremento en los últimos 15 años, debido a su demostrada rentabilidad en la detección precoz del cáncer de mama, pues contribuye a reducir la mortalidad e incrementar el número de tratamientos conservadores. Diversos estudios han demostrado la utilidad de realizar mamografías a mujeres asintomáticas en las edades de mayor riesgo, en la cuarta, quinta y sexta décadas de la vida [1].
Técnicamente, la mamografía se realiza mediante películas radiográficas de una sola emulsión y una pantalla de refuerzo, con un sistema de procesado automático dedicado. Utilizar una emulsión simple en lugar de doble permite conseguir mayor resolución espacial a costa de disminuir la sensibilidad del sistema. Para la obtención de imágenes de calidad diagnóstica en una zona anatómica con bajo contraste de objeto como es la mama, es preciso que el receptor de imagen ofrezca suficiente contraste intrínseco.
Uno de los elementos clave en la calidad de imagen mamográfica y la dosis suministrada por exploración es el sistema pantalla-película empleado. En tal sentido, el contraste y la sensibilidad de dicho sistema, que pueden determinarse mediante técnicas de sensitometría, son parámetros técnicos que deben evaluarse como un estándar de calidad. Parámetros sensitométricos como el gradiente o la velocidad están relacionados con el contraste y la

sensibilidad del sistema, es decir, con la calidad de imagen y la dosis empleada respectivamente.
El procesado afecta tanto al gradiente como a la velocidad. Los principales factores que afectan ambos parámetros son: el tiempo de inmersión en el baño de revelado, la temperatura de revelado y el grado de reciclado de los líquidos. Los fabricantes han desarrollado diferentes tipos de películas y pantallas de refuerzo, recomendándolas para ciclo estándar (90s), extendido (180s) o ambos. El objetivo de este trabajo es comparar las variaciones de gradiente y velocidad inducidas por dos tipos de productos químicos de procesado, mediante sensitometría de luz y de rayos X.

3. Material y método
En el presente trabajo se ha realizado un estudio comparativo incluyendo 13 películas y 9 pantallas de refuerzo para mamografía, comercializadas por seis fabricantes diferentes.

3.1. Sensitometría de luz
Se han utilizado trece películas comercializadas por 6 fabricantes: Trimax FM, Trimax HM y Trimax HM2 (Imation); MR3-II, MR5-II y MR6 (Agfa); UM-MA HC (Fuji); Min-R MA, Min-R E y Min-R 2000 (Kodak); CM-New y CM-H (Konika), y Microvision-C (Sterling).
Las películas se expusieron con un sensitómetro de luz verde (07-456 Victoreen), que proporciona una tira de 21 escalones de diferente exposición (E), que aumenta 0,15 LogE en cada escalón, desde 0,05 hasta 3,05. Una vez expuestas, las películas se procesaron en 6 condiciones de procesado diferentes (Tiempo de procesado/Líquidos/temperatura del revelador): 90s/Kodak/37.6°C, 120s/Kodak/34.3°C, 180s/Kodak/34.7°C, 90s/Agfa/34.0°C, 120s/Agfa/34.0°C y 180s/Agfa/34.7°C.
Los líquidos(revelador/fijador) Kodak fueron RP X-Omat EX/LO, y los Agfa fueron G139/G334. El tiempo de procesado se midió desde la entrada en el baño de revelado hasta la salida eal exterior (tiempo seco-seco).
La densidad óptica de la tira sensitométrica se leyó mediante un densitómetro digital (07-424 Victoreen). Se obtuvieron las curvas características de logE frente a densidad óptica (DO) y se calculó la velocidad como el inverso del LogE necesario para alcanzar una DO de 1+velo+base (1+VB), siendo VB la densidad óptica obtenida sin exposición. El gradiente medio se calculo como la pendiente entre DO iguales a 0,25+VB y 2+VB
El procedimiento concreto se repitió cuatro veces. Los resultados se presentan en términos de la media de las cuatro series.

3.2. Sensitometría de Rayos X
Para este estudio, se realizó sensitometría de rayos X, mediante una cuña escalonada de aluminio, a 99 combinaciones pantalla/película (11 películas combinadas con 9 pantallas de refuerzo) en dos unidades mamográficas diferentes (UC Mammo Diagnostic y Senograph 800T), con procesados de 120s, y líquidos Kodak y Agfa respectivamente. La cuña de aluminio se calibró para cada unidad empleando dosímetros de termoluminescencia. La velocidad se calculó como el inverso de la exposición necesaria para obtener una DO de 1+VB y el gradiente medio como se ha descrito en la sensitometría de luz. El procedimiento se repitió con las 99 combinaciones tres veces, en días diferentes y los resultados se presentan en términos de media y desviación estándar.

3. Resultados y conclusiones
En la sensitometría de luz, el incremento del tiempo de procesado repercute en un aumento de la sensibilidad o el gradiente más marcado, según se empleen líquidos Agfa o Kodak, respectivamente (Figura 1).

Los resultados de la sensitometría de luz han sido presentados con detalle anteriormente [2]. Sería deseable haber utilizado una procesadora única, pero es una tarea cara y difícil de conseguir. Desafortunadamente la temperatura de revelado de la procesadora a 90s/Kodak excedió en 3 °C a las restantes, lo cual debe tenerse en cuenta.

Todas las películas alcanzaron la mayor velocidad, en términos absolutos con procesado Kodak/118s. La desviación estándar de las cuatro series varió entre 0,00 y 0,03. Al evaluar los resultados entre 90s y 120s asi como 120s y 180s, puede verse que la relación entre velocidad y tiempo de procesado es muy diferente según el tipo de químicos empleado. Con líquidos Kodak, la velocidad aumentó siempre según se incrementó el tiempo de procesado, pero con líquidos Agfa no varió o incluso disminuyó en un 84% de los casos.

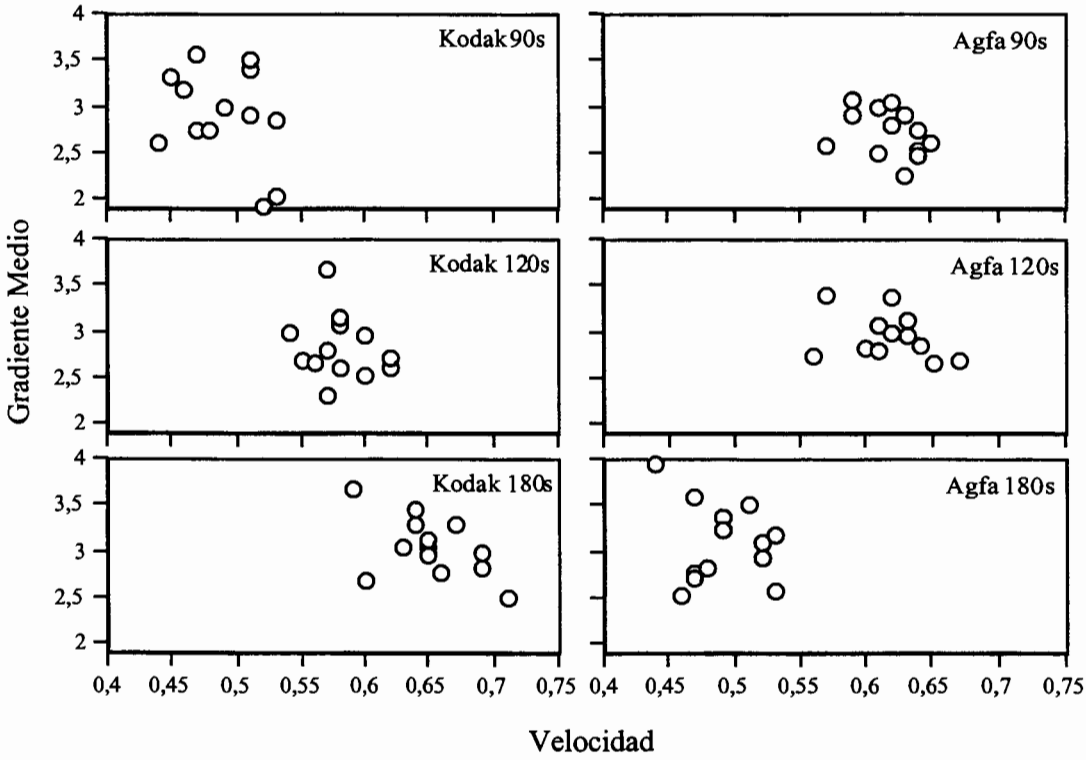

Figura 1.- Sensitometría de luz. Se presenta el gradiente medio de las 13 películas estudiadas frente a la velocidad empleado diferentes tipos de procesado: químicos Kodak y Agfa a ciclos (seco-seco) de 90, 60 y 120 s

Los resultados de la sensitometría de rayos X (ciclo 120 s) mostraron una mayor velocidad del sistema pantalla película cuando se emplearon líquidos Agfa (Figura 2). Estos resultados coinciden con lo encontrado en la sensitometría de luz para un ciclo de 120 s (figura1). La utilización de químicos Kodak, en cambio, muestran un cociente gradiente velocidad mayor que con procesado Agfa (figura 3). Esta tendencia a favorecer velocidad o contraste según los químicos de procesado empleados no ha sido descrita anteriormente en nuestro conocimiento.

Utilizar películas mamográficas con un contraste intrínseco elevado es uno de los objetivos a conseguir en mamografía de pantalla-película [3], debido a que el contraste que se presenta al radiólogo es el resultado del contraste de objeto a los rayos X y el gradiente del receptor de imagen.

Nuestros resultados muestran que las variaciones de tiempo de procesado influyen de manera muy distinta en velocidad y gradiente, dependiendo de los químicos de revelado empleados. Esto ha sido corroborado al emplear combinaciones pantalla-película, exposición a rayos X en dos mamógrafos calibrados y procesado a 120 s. En estas condiciones la dosis a pacientes y el contraste de imagen son altamente dependientes de los químicos de revelado empleados para

un gran rango de combinaciones pantalla-película. Sería interesante comprobar la sensibilidad y contraste a los rayos X con ciclo corto y extendido, así como con otros tiempos de revelado.

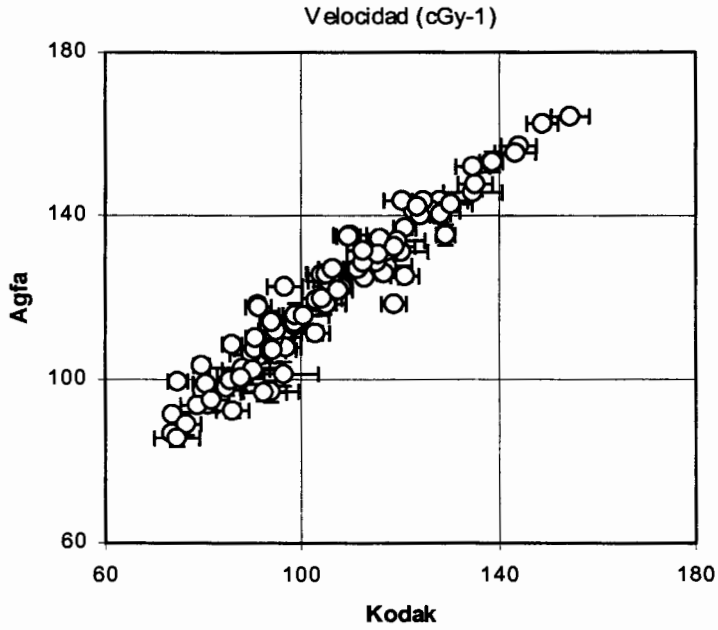

Figura 2.- Sensitometría de rayos X. Velocidad obtenida por cada una de las 99 combinaciones pantalla película según los químicos empleados (120 s seco-seco). Se presenta la media de tres observaciones. Las barras de error corresponden a la desviación estándar.

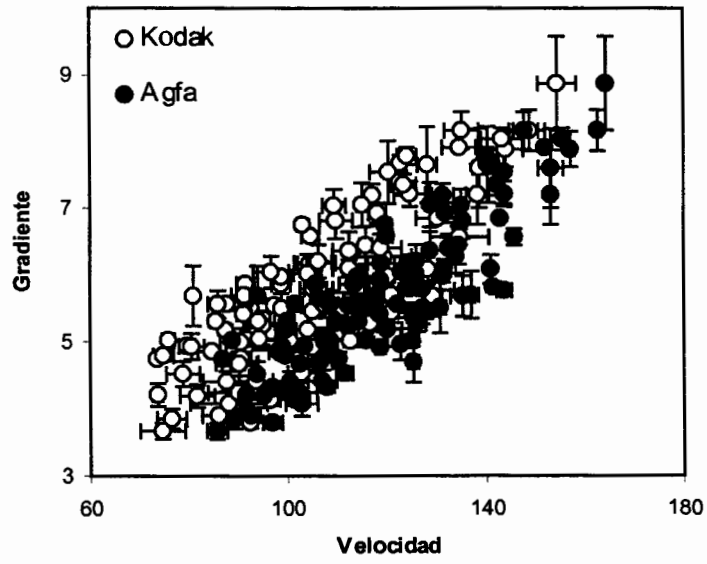

Figura 3: Sensitometría de rayos X. Representación gráfica de velocidad frente a gradiente para las 99 combinaciones pantalla película, con procesado AGFA (puntos negros) y Kodak (puntos blancos).

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Pediatric

IAEA-CN-85/172

RADIATION DETRIMENT ASCRIBABLE TO INFANTS AND CHILDREN UNDERGOING MICTURATING CYSTOURETHROGRAMS - A REVIEW OF STUDIES IN SPAIN, BRITAIN, NEW ZEALAND AND VENEZUELA

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Abstract

The detriment, due to ionizing irradiation, ascribable to infants and children may be as high as three times that to adults. Recent interest in dose reduction, in part associated with the advent of the Diamentor dose-area product meter has led to several studies reporting average dose-area products at a number of centres for micturating cystourethrograms (MCUGS) and other radiological examinations. In this review the data has been further processed to yield the ICRP 60 Equivalent Doses and a detriment factor applied to yield the numbers of infants likely to suffer detriment in future lie as a result of having undergone the procedure at the centres reviewed.

Introduction

The ICRP Publication 60 [1] recognizes that the detriment which people might incur from irradiation needs to be in line with the other risks in life that people are willing to accept. Partly as a result of this and better knowledge concerning the detriment imposed by irradiation the ICRP reduced its recommended limits for exposure to radiation. Amongst other things it re-defines various quantities so as to make predictions of the outcomes of irradiation easier to quantify and understand. An initiative of the Commission of European Communities [2] inspired an interest in the assembling of data on paediatric radiology, there being a paucity of that in the literature.

The use of Monte Carlo methods for studying radiation transport and energy deposition when coupled with mathematical models of the human anatomy has enabled the calculation of tables of organ does normalized to Entrance Surface Doses and separately to Dose-area Products for a set of standard radiographic projections. Such tables have been published by Hart, Jones & Wall at the NRPB [3] for adult radiology, computed tomography and paediatric radiology. Computer software (CHILDOSE) has been published by J Le Heron ar the NRL [4] which utilizes these tables and specific input parameters such as the filtration, kVp and either entrance surface dose or dose-area product to make dose calculations. It enables the user to choose the standard examination required and calculates the doses to all organs (of both genders) and the Equivalent Dose (E D) to the person as a whole. In certain instances the actual examination may only be able to be approximated by one of the standard projections or may be somewhere between two of them. When fluoroscopy is involved covering several organs such as the genitourinary tract practical experience shows that up to three of the standard examinations may have to be calculated to give a good indication of the contributions to the Effective Dose.

The detriment a human being may suffer as a result of irradiation may be no harm, the induction of a non fatal cancer, the induction of a fatal cancer and/or gonadal damage resulting in genetically deficient offspring. The susceptibility of adults to suffering such detriment (including the loss of lifestyle effected by cancers and genetic defects) may be broadly desribed by detriment factors of 5%/*Sv* of dose for fatal cancers,1%/*Sv* of dose for non fatal cancers and 1.3%/*Sv* of dose for genetic effects in offspring. (ICRP 60 Sect 97 [1]).

The susceptibility of children to suffering the detrimental effects of radiation is considerably greater than that for adults, but decreases exponentially into adult-hood. For those aged under 10 years of age

the 'multiplicative' model of susceptibility suggests that the susceptibility of children receiving low doses of radiation leading to fatal cancers later in life is approximately 3 times that of adults - that is about 15%/*Sv*. (ICRP 60 [1] Fig. C-5 Annex C.7). Assuming that the same factor of 3 may be applied to the other two much smaller contributions to detriment the factors would be 15%/*Sv* of dose, 3%/*Sv* of dose and 4%/*Sv* of dose for fatal, non-fatal and hereditary effects respectively - a total of 22%/*Sv* of dose. This assumption is probably the most reasonable that can be made at this time as not sufficient time has elapsed for the 'under 10 years of age' Japanese atomic bomb survivors to have completed their life span for the relevant statistics to have been compiled. Those such survivors presently alive would be between 55 and 65 years of age.

The detriment (*D*) is calculated by firstly calculating the Effective Dose (*ED*) and then multiplying that by the detriment factor (*f*) which may be styled

$$D = ED.f$$

The figure of 22%/*Sv* of dose would seem to be a reasonable upper bound in this instance. The 'multiplicative' model is much more conservative than the 'additive' model - predicting higher susceptibilities to radiation detriment for children than the additive model.

Method

Review papers from the period 1994 - 1996 were chosen where there was suitable data on micturating cystourethrograms presented.

The tables of NRPB SR279 and the software published by the New Zealand National Radiation Laboratory (NRL) were used to make a series of calculations of the average Equivalent Doses using the average dose information and radiological settings from the selected studies.

CHILDOSE has options to calculate doses for a child at birth, 1 year, 5 years and older ages. As the data reported in the selected literature is given as an average for the periods 0 - 12 months, calculations of the Effective Dose at birth and 1 year may be calculated along with the values of their arithmetic mean (denoted by - 6 m (months)). This average should then reasonably represent the Effective Doses for the average dose-area products, and kVp's reported.
The filtration in one of the reported studies is 3.1 mm Al. Whereas the remainder do not report the filtration used. In such instances 3.0 mm Al is used in the calculations for this report.

An MCUG study on an individual patient generally comprised two part - a fluoroscopic part and an X-ray part where 3 - 6 exposures are taken. Quite a variety of diagnostic regimens are followed leading to a rang of results varying by an order of magnitude. Generally the kVp is around 65 but in some instances it is around 90. The average dose-area products are generally reported, in the papers, separately for the fluorography and the films (and these may have been made at different kVp's) so the calculations of dose are done separately and the results summed.

Results and Discussion

The radiological parameters and results of the calculations are presented in Table 1. They have been arranged in order of publication.

The Author Abbreviations refer to the publications as follows - DLE- Evans [5], MFSM – Martin, Farquhar, Stockdale & MacDonald [6], GVR – Gonzalez, Vano & Ruiz [7], KFCPB –

Kyriou, Fitzgerald, Pettett, Cook & Pablot [8]. RVGF – Ruiz, Vano, Gonzalez & Fernandez [9]. The meanings of the Centre's I, II, and III C1, C2, G3 and G4 are as defined in the papers to which they apply.

Table 1 Effective Doses and Detriment Calculated for a Range of Reported MCUG Surveys of Radiological Practice

Year	Author	Filtn.	kVp	kVP	ESD	ESD	Diament.	Diament.	AP View	E D	E D	E D	Detriment
of Publ.	Abbrevn.	mm Al	Flu	Film	Flu mGy	Film mGy	Flu cGycm^2	Film cGycm^2		0 m mSv	12 m mSv	~6 m mSv	0.22/Sv
1993	DLE	3.1	60	60	0.77	1.41			Abdomen	0.6	0.4	0.5	
									Pelvis	0.5	0.4	0.4	
									U Bladder	0.5	0.4	0.5	1 per 10,000
1994	MFSM	3	70	70			17	3.6	Abdomen	0.5		0.4	
									Pelvis	0.5	0.3	0.4	
									Abdomen	0.6	0.4	0.5	1 per 10,000
1995	GVR	3.1	85	55			20	238	Abdomen	5	2.3	3.7	
	Centre I								Pelvis	5.4	2.8	4.1	
									U Bladder	6.1	4	5.1	11 per 10,000
	GVR	3.1	95	75			134	117	Abdomen	7.2	3.1	5.2	
	Centre II								Pelvis	6.5	3.4	5	
									U Bladder	7.3	4.9	6.1	13 per 10,000
1996	KFPCB*	3.1	62	62			39		Abdomen	0.8	0.4	0.6	
	C1 & C2								Pelvis	0.9	0.4	0.7	
									U Bladder	1	0.6	0.8	2 per 10,000
	G3 & G4	3.2	65	65			174		Abdomen	3.7	1.7	2.7	
									Pelvis	4	2	3	
									U Bladder	4.5	2.9	3.7	8 per 10,000
1996	RVGF	3.1	60	65			116	10	ABdomen	2.5	1.2	1.9	
	Centre I								Pelvis	2.8	1.4	2.1	
									U Bladder	3.1	2	2,6	6 per 10,000
	Centre II	3.1	80	100			117	165	Abdomen	7.2	3.6	5.4	
									Pelvis	7.6	4.2	5.9	
									U Bladder	8.5	5.7	7.1	16 per 10,000
	Centre III	3.1	65	70			57	57	Abdomen	2.5	1.2	1.9	
									Pelvis	2.6	1.4	2	
									U Bladder	3	2.-0	2.5	6 per 10,000
2000	DLE&MCC												

*Film and Fluorographic values are not given separately, just the total is given and that is the v alue in the Flu. Column.

The standard radiological examinations dealt with by CHILDOSE do not include the MCUG so calculations have been made of the organs doses for the three examinations Abdomen, Pelvis and U bladder. The Abdomen does not include the testes whereas the Pelvis and U bladder do. Which is the most realistic representation is hard to decide but the results do not differ greatly. Readers must pass their own judgement on this matter.

As the calculations parameters for each of the three examination projections are all the same they have not been repeated on Table 1 so those given for the Abdominal projection are used for the Pelvic and U bladder projections also.

The regions of the body, of interest to this study, for which the software makes calculations are shown for the 0 year old child in Figure 1 and for 1 year old child in Figure 2. These diagrams are reproduced from NRCP-SR279 [3] with the kind permission of B F Wall. The dashed lines define the area being irradiated.

The values of the Effective Dose – E D are those calculated by CHILDOSE using the NPRB tables. Method 1 [4], (the method recommended by the author of CHILDOSE), of the four methods available was used. [The different methods relate to the treatment of the remainder organs in the calculations.]

The detriment D is calculated as 22%/*Sv.ED* where for the purposes of these calculations 1 *mSv* = 1 *mGy* and is expressed in the form *n* per 10,000. This means that *n* infants of every 10,000 undergoing this diagnostic procedure at the relevant institution at the time to which the survey data pertains or having an examination using the same or similar radiological parameters would incur a radiological induced detriment. For 15/22 of those incurring the (non-zero) detriment the detriment would be a fatal cancer some time later in life, for 3/22 of them the detriment would be a non-fatal cancer later in life and for 4/22 of them the detriment would be inheritance of a genetic defect by their offspring.

Examination of Table 1 shows that there are widely varying practices with accompanying disparate detriment.

Conclusion

There is significant variation in the detriment being suffered by infants having MCUG examinations at different centres around the world. The average Effective Doses calculated corresponding to the average parameters used in the calculations range from 0.5 - 7.1 *mSv*. The range of actual Effective Doses will of course be even wider. If the method were to be compared with some other modality the diagnostic information yield obtainable from each modality would have to be carefully compared particularly in relation to specificity and efficacy. The availability of detriment information certainly makes it easier to quantify the relative risks of various procedures in order to make informed decisions about them.

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ESTIMACION DE LA COMPONENTE DE TRANSITO EN LA DOSIS DE BRAQUITERAPIA CON ALTA TASA DE DOSIS

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Abstract

Current high dose rate brachytherapy (HDR) treatment planning systems usually calculate dose only from source stopping positions (stationary component), but fails to account for the administered dose when the source is moving (dynamic component or transit dose).
Numerical values of this transit dose depends upon the source velocity, implant geometry, source activity and prescribed dose. In some HDR treatments using particular geometry the transit dose cannot be ignored because increase the dose at the prescriptions points and also could increase potential late tissue complications as predicted by the linear quadratic model. International protocols recommend to verify this parameter [1]. The aim of this paper has been to establish a procedure for the transit dose calculation for the Gammamed 12i equipment at the RT Department in the Clinical University Hospital (Zaragoza-Spain). A numeric algorithm was implemented based on a dynamic point approximation for the moving HDR source and the calculated results for the entrance-exit transit dose was compared with TLD measurements made in some discrete points.

Resumen

Los sistemas de planificación asociados a equipos de alta tasa de dosis (HDR) suelen calcular la dosis suponiendo que la única contribución se debe a cuando la fuente se encuentra en las diferentes posiciones de parada (componente estacionaria), sin tener en cuenta la dosis suministrada cuando la fuente está en movimiento (componente dinámica o de tránsito).
La magnitud de la dosis en tránsito depende fundamentalmente de la velocidad de la fuente, la geometría del implante, la actividad de la fuente y la dosis prescrita, y, en determinadas aplicaciones de Alta Tasa esta dosis puede llegar a ser significativa en cuanto al incremento de potenciales complicaciones tardías en los tejidos sanos, y su estimación está recomendada en los protocolos de verificación [1]. El propósito de este trabajo ha sido establecer una sistemática de cálculo de la componente de tránsito de la dosis, para el equipo Gammamed 12i existente en el Servicio de RT del HCU de Zaragoza. Se ha desarrollado un programa de cálculo y los resultados de dosis entrada-salida calculados se han comparado con medidas hechas con TLD en puntos discretos.

Método y resultados

Teoría general

La dosis total en un punto puede considerarse debida a dos componentes, una depositada cuando la fuente se encuentra en reposo (Ds) y la otra cuando se encuentra en movimiento (Dd), de forma que: $DP = Ds + Dd$.
El cálculo de Ds se lleva a cabo por el algoritmo definido en el Sistema de Planificación.
Para la estimación de Dd es preciso tener en cuenta a su vez otras tres contribuciones debidas a la fuente en su recorrido de: entrada al aplicador, entre posiciones de parada y salida del

aplicador para recogerse en el equipo [2]. Podemos expresarlo como:
$Dd = D_{entrada} + D_{entre\ posiciones} + D_{salida}$

En definitiva, cada componente de Dd depende de la distancia entre el punto considerado para el cálculo y el punto en que se encuentra la fuente en cada momento, así como del tiempo que le cuesta a la fuente recorrer cada intervalo de espacio (velocidad de la fuente).

Velocidad de la fuente

Puede comprobarse [2,3] que la fuente no se desplaza a velocidad constante en todo su recorrido sino que esa velocidad depende del espacio que recorre. Para el equipo Gammamed 12i no hemos encontrado en la documentación ni en la bibliografía estimación de valores para este parámetro, por lo que ha sido preciso realizar una determinación experimental del mismo.

Mediante un cronómetro se han medido:

- Tiempos de entrada y salida en el recorrido máximo de la fuente que para este equipo es de 1300 mm (utilizando la fuente de simulación para tener una observación más directa). Se obtuvo un valor de 433 mm/seg.

- Tiempos entre paradas, planificando múltiples paradas a intervalo constante, y para diferentes intervalos. En este caso, como ha debido realizarse con la fuente real, se han estimado tiempos totales y se han restado los de entrada y salida así como los de parada seleccionados, para determinar el tiempo empleado en recorrer la totalidad de los espacios inter-parada. Como se conoce el número de espacios y el intervalo entre paradas puede calcularse la velocidad de la fuente en ese recorrido.

Los resultados obtenidos se muestran en la figura 1, y son análogos a los publicados en (2) por otros autores para el equipo Nucletron.

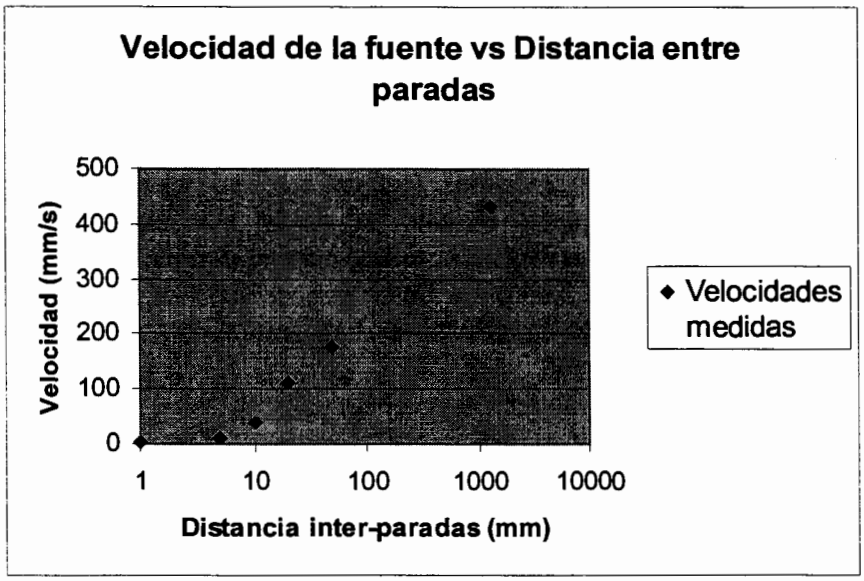

Figura 1. Velocidad de la fuente de Ir-192 del equipo Gammamed 12i de HDR, en función de la distancia entre paradas.

Estimación teórica de Dd

Se ha preparado un programa de ordenador en lenguaje C++ para el cálculo teórico de la dosis dinámica en un aplicador lineal, integrando numéricamente la contribución a la dosis de

la fuente a lo largo de todo el recorrido. Una vez introducido el valor de la tasa de kerma en aire de la fuente es preciso introducir la velocidad estimada para la componente de que se trate.

Para las componentes $D_{entrada}$ y D_{salida} el tiempo de irradiación de cada intervalo de integración se calcula suponiendo la velocidad constante e igual a los 370 mm/seg que habíamos determinado.

Para la estimación de $D_{entre\ posiciones}$, es preciso introducir el intervalo entre paradas y el número de paradas, así como la velocidad estimada a partir de la gráfica de la figura 1.

Para el cálculo de dosis se han utilizado los mismos factores que utiliza el sistema de planificación Abacus.

Verificación del algoritmo

Se han realizado medidas de dosis de entrada y salida con dosímetros TLD 100, calibrados previamente para la energía del Co-60, dispuestos según el esquema de la figura 2.

Los dosímetros son de 3.2x3.2x0.9 mm^3 y se leyeron con un lector 2800M de Victoreen, utilizando un programa de lectura de 10" a 160° y 10" a 300°. El programa de borrado utilizado es de 1h 400° y 8h a 100°.

Se programó una única posición de parada de 1 segundo a una distancia de 29 cm del dosímetro más próximo, de forma que puede considerarse despreciable la contribución estacionaria de dosis.

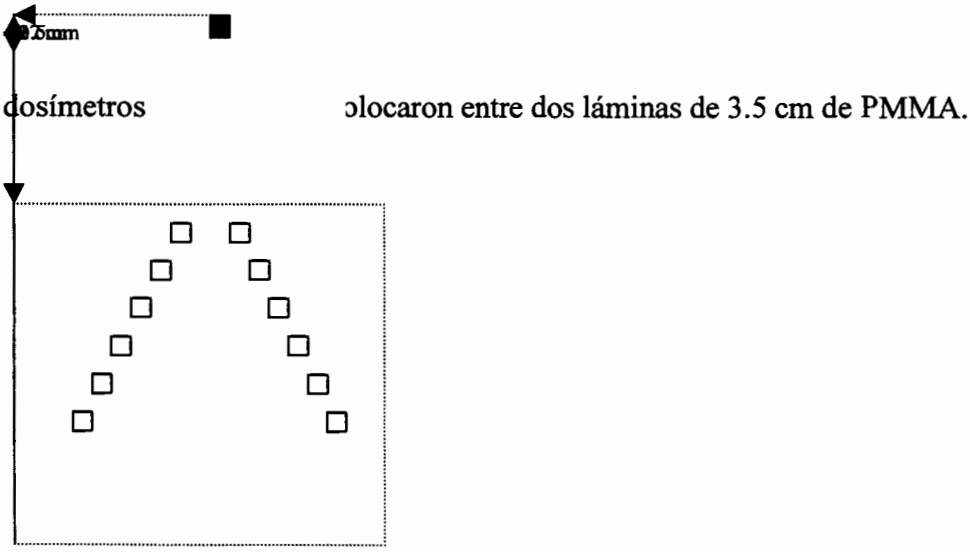

Figura 2. Esquema de colocación de los dosímetros TLD para medida de dosis en tránsito.

La comparación entre los resultados experimentales y los calculados por el algoritmo se muestra en la figura 3. Las diferencias encontradas son del orden de las estimadas en [2].

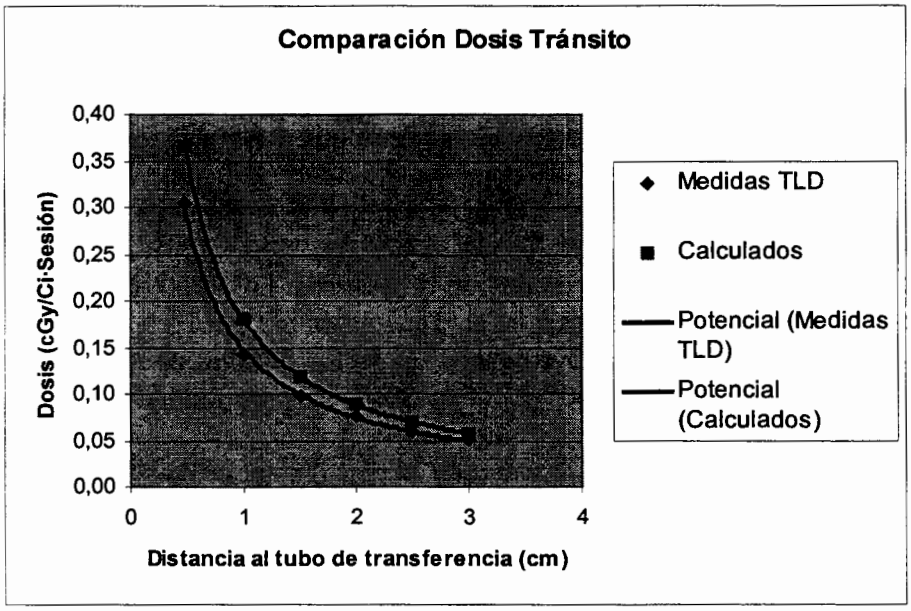

Figura 3. Comparación de valores de dosis de tránsito experimentales y calculadas.

Conclusiones

Dado que la dosis en tránsito es linealmente dependiente de la actividad de la fuente, del número de fracciones y de la velocidad de tránsito, y a la vista de los valores de dosis obtenidos por unidad de actividad y sesión, la contribución de esta componente de dosis en tejidos alrededor de la fuente puede llegar a ser considerable en el caso de que el número de fracciones sea grande y aumente el número de canales utilizados, por lo que en esos casos no debería despreciarse como suele hacerse en los sistemas de planificación asociados a equipos de HDR.
El algoritmo desarrollado resulta práctico para el cálculo de la dosis en tránsito.

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DUAL-SLICE SPIRAL SCANNER : DOSES DELIVERED DURING THORACIC AND ABDOMINAL EXAMINATIONS

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ABSTRACT

A new dual-slice spiral scanner (PICKER-ELSCINT CT-Twin) dedicated to thoracic and abdominal examinations being implanted in our hospital, a dosimetric study was performed in order to evaluate the dose delivered to different body parts (skin, mid-thickness, lungs, etc) as a function of the CT parameters used for the most current protocols (determined by a statistical study including 250 patients). The aim was to establish a simple method allowing a quick estimation of the dose delivered to the patients knowing CT parameters used (kV, mAs/slice, pitch, slice thickness...).

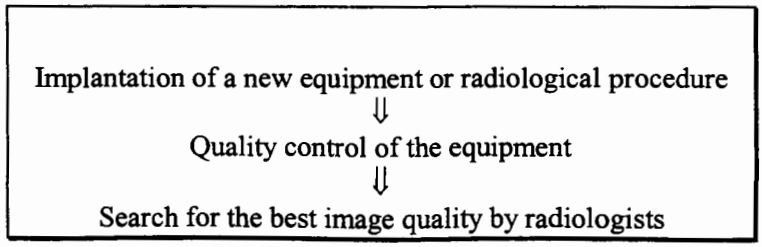
Dosimetric measurements were performed using an Alderson anthropomorphic phantom and $Li_2B_4O_7$:Cu TL powder (chosen because of its flat energy response in the studied energy range). Results obtained (precision: ± 5%) have shown that doses are dependent on the number of scans, mAs/slice and kV but very little dependent on slice thicknesses. For instance, doses at the abdomen center of patients irradiated at 120 kV vary from 0.7 to 1.7 cGy for mAs varying from 133 to 333 with a variation less than 10% when one passes from "pitch 0.7- thickness 8 mm" to "pitch 2- thickness 13 mm". Other charts and tables deduced from experimental results will be presented. They show that doses delivered by helical computed tomography being relatively high, the number of procedures and section per procedures should be carefully adapted to the age of patients and the underlying pathology.

Key-words: Computed Tomography, radiation protection, TLD, radiological doses

1. INTRODUCTION

The knowledge of the absorbed dose delivered during radiological procedures is an indispensable step to estimate the radiation risks associated with a given procedure and therefore to optimize it with respect to the radiation risk and the risk-benefit analysis (underlying pathology, patient's age, etc). As it is a long and cumbersome work to evaluate it for each patient and the different radiological procedures in use, we prefer to undertake a dosimetric study every time a new radiological equipment or a new procedure is implanted in a department of radiology, following the method shown in Figure 1.

The evaluation of the doses delivered during thoracic and abdominal examinations performed with a dual slice spiral scanner will be presented as an illustration of the method.



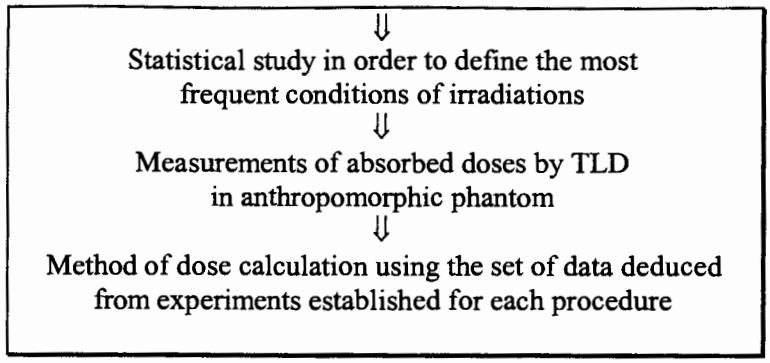


Figure 1: General method followed at Hospital Henri Mondor for evaluation of the patient's dose

2. MATERIALS AND METHOD

2.1. CT equipment

A whole body dual-slice spiral computed tomography (CT) CT-Twin PICKER-ELSCINT was used. It permits rapid scanning of a large volume of tissue, the X-ray tube rotating continuously in a circular motion while the patient is transported on a table at a constant velocity through the center of the circle, so that the X-ray beam describes a spiral path through the patient [1]. Moreover the CT-Twin offers the particularity to have a wide fan beam of X-rays striking two side-by-side parallel arcs of detectors, producing a double spiral of spatial information. Data are interpolated from the raw data collected with the two detectors arrays. Such CT permitting to achieve faster scanning compared single-slice spiral ones [2] are relatively new so that only a few dosimetric data are available for them.

Irradiation parameters used for the present study were:

- Helix mode, i.e. dual-slice spiral mode
- Scan diameter 430 mm
- Voltages: 120 and 140 kV
- Number of mAs/slice varying from 100 to 333
- Pitch values (defined as the table feed distance per 360° rotation divided by the nominal section thickness): 0.75, 1 and 2
- Slice thickness varying from 8.8 to 13 mm.

They cover all the range of irradiation parameters noted in the files of 250 patients submitted to thoracic and abdominal examinations.

2.2.Phantom

Experiments have been performed by simulating patients of average size with an anthropomorphic phantom type ALDERSON and irradiating it in the different conditions used for patients (see §2.1). In order to improve the accuracy, multiple scans on the same area have sometimes been made, and the dose obtained divided by the number of scans.

2.3. Thermoluminescent dosimetry (TLD)

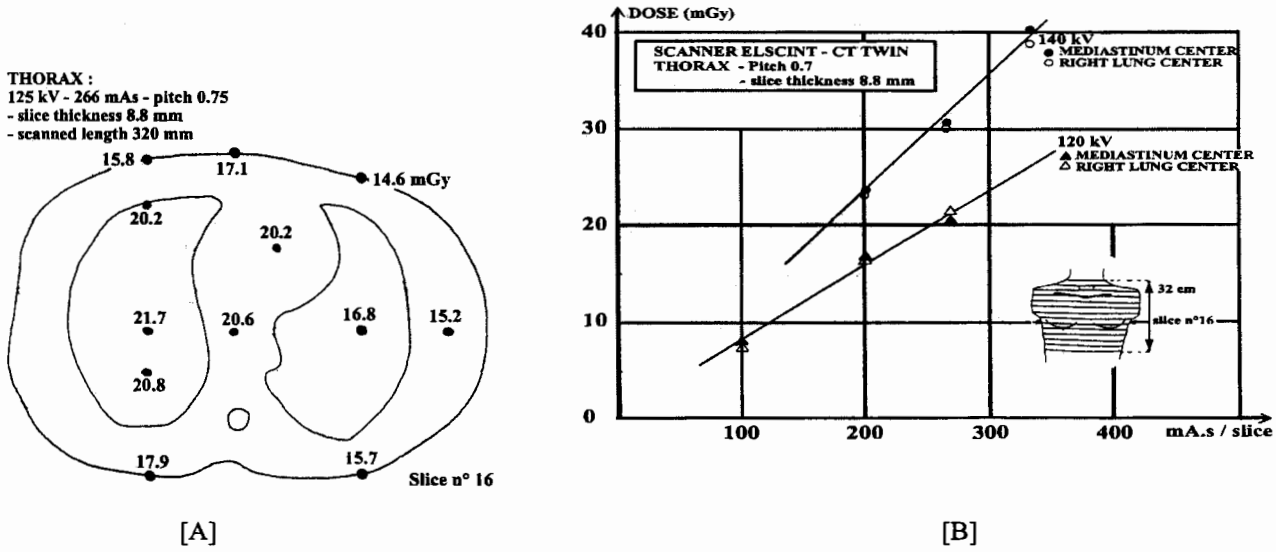
Experiments were performed using $Li_2B_4O_7$:Cu TL powder [3] chosen because of its energy response better than LiF in the energy range of diagnostic radiology [4, 5]. As an indication, the mass energy absorption ratio of $Li_2B_4O_7$:Cu and Lif to tissue in the energy range 20 to 200 keV, vary of 11% and 43%, respectively.

TL powder was spread out in very thin envelops made of black paper and stuck at the entrance and exit surface of the Alderson phantom (for evaluation of the skin doses), or contained in opaque cylindrical containers which were inserted in the holes of the phantom for evaluation of the dose at mid-thickness or within the organs). previously to experiments a direct calibration of the powder under both the presentations have been carried out by comparing its response to the response of a calibrated ionization chamber specially dedicated to low-energy X-rays.

After irradiation, TL powder was read out on an automatic FIMEL-PCL 3 reader [6] (preheating temperature: 178°C, heating temperature : 403°C, no annealing of TLD after readout) and results obtained with an intrinsic precision of $\pm$ 5%.

3. Results

An example of the results obtained for a slice of the Alderson phantom situated close to the center of the explored region and irradiated at 120 kV –266 mAs (pitch 0.75, slice thickness 8.8 mm, length of the scanned volume 320 mm) are shown in Figure 2-A. Results obtained for other conditions of irradiation and other scanned volume have shown that the delivered doses are essentially dependent on the number of scans, voltage and mAs/slice [Figure 2-B] but very little dependent on the cut thickness. For instance, doses at the abdomen center irradiated at 120 kV (currently used for patients of average size) vary from 7 to 17 mGy for mAs varying from 133 to 333 and can reach 28 mGy for 340 mAs at 140 kV (often used for thick patients). Skin abdominal doses are higher than dose at the abdomen center, varying from 10 to 26 mGy at 120 kV, and reaching 37 mGy at 140 kV. Similar measurements performed at the thorax level have shown comparable skin doses but higher doses at the lung centers, the dose variation being from 10 to 24 mGy at 120 kV for mAs varying from 133 to 333.



[A] [B]

Figure 2: Example of results obtained by TL measurements at differents points of a slice of an Alderson phantom irradiated in patient conditions [A].
Graphic data which can be deduced from numerous measurements [B].

From all the experimental results obtained we have established a set of simple charts and tables giving the doses for 100 mAs/slice (see example shown in Table 1). The dose delivered to a patient can be deduced from them knowing the actual number of mAs used for the patient examination, and of course using the chart or table corresponding to the other irradiation parameters used.

ELSCINT – CT_{TWIN} (Helix mode)

Doses (mGy) for 100 mAs/slice

(Pitch = 0.75 – slice thickness = 8.8 mm)

Voltage	THORAX *			
kV	Skin	Mediastinum	Lung Center	
			Right	Left
120	6.1	8.1	8.1	6.7
140	9.1	11.9	11.9	10.2

** Measurements performed with slice n°16 (Alderson phantom)*

Table 1

When the radiological examination is performed a pitch and a cut thickness different from those of the basic data, correction factors must be introduced to estimate the patient dose. A set of correction factors taking into account the difference of pitch (F_{pitch}), the difference of slice thicknesses (F_{slice}) and the difference in patient thicknesses ($F_{thickness}$) have also been established experimentally, so that the dose in any irradiation condition can be approximated from the following relationships:

$$\text{Dose} = D_o \times \frac{\text{mAs}}{100} \times (F_{pitch}) \times (F_{slice}) \times (F_{thickness})$$

The validity of the above relationships has been checked experimentally.

4. CONCLUSION

The method previously described can be easily used in radiology departments in which protocols of irradiation procedures are clearly defined and practically applied. It allows a good approximation of doses delivered to each patient which can be noted in his medical file.

Experimental results obtained have also pointed out that doses delivered by helical computed tomography being relatively high, the number of procedures and the length of the examined volume
should be carefully adapted to the age of patients and the underlying pathology.

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Use of the EU quality criteria as a common method of inspecting CT laboratories– a pilot project by the Nordic radiation protection authorities

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Abstract: In the frame of Nordic radiation protection co-operation quality criteria for computed tomography (CT) as published by the European Commission were used for the evaluation of selected CT laboratories in each of the Nordic countries. The mean values for all five countries of the weighted CT dose index ($CTDI_w$) and dose length product (DLP) were 60 mGy and 270 mGy·cm for CT of the brain, 11 mGy and 230 mGy·cm for CT of the chest, and 40 mGy and 590 mGy·cm for CT of the lumbar spine, respectively (Swedish values so far). A comparison with the reference levels set in the above mentioned publication gives a diversified result: compliance for the DLP-values is generally achieved with god margins whereas the $CTDI_w$–values were frequently larger for brain and lumbar spine examinations. The radiographic technique was generally also within the recommendations from the EC. Nearly all image quality criteria were fulfilled, but it must be born in mind that the study was biased in the way that two local radiologists in consensus evaluated their own images. Image material from only three patients was selected for each of the clinical indications, that means the project was not designed for ranking laboratories, but it is a way of making the departments aware of the need for optimisation regarding image quality and patient dose, and also on the problems associated with this task. During the study suggestions were brought forward concerning amendments of the quality criteria: some need a better definition, some are not relevant for the diagnostic task in question, some could be added. Instead of "yes" and "no" a range of maybe 5 levels of visualisation should be introduced in order to better characterize the level of diagnostic performance.

1. Introduction

The radiological society has for long been aware of the increasing contribution from computed tomography (CT) to the collective effective dose. The reduction of exposures by requiring optimisation of CT procedures is therefore of principal concern in radiological protection. The concept of "diagnostic reference levels" was promoted by the International Committee on Radiological Protection (ICRP) in 1996 [1], and adopted in the Medical Exposure Directive [2] by the European Commission, which also recently provided a set of image quality criteria for various CT procedures [3]. The radiation protection authorities in the five Nordic countries have for long been co-operating on surveys of patient doses in diagnostic radiology [3, 4], and

also on legislation and inspection strategies. Within the frame of Nordic radiation protection co-operation a pilot project was initiated. The goal was to try whether the EC quality criteria for CT can be used as an inspection tool, and as a way of getting in touch with the local clinical practice.

2. Materials and methods

Data from five hospitals in each of the Nordic countries were collected. The image quality was evaluated according to the EU quality criteria for three examination types, with suggested specific clinical indications (to ensure that the patient group is homogenous): (a) Brain, general (differential diagnosis of haemorrhage versus thrombosis/emboli) (b) Chest, general (suspected lung metastasis), and (c) CT of Lumbar Spine, discal herniation (sciatica/disc diagnosis, uncertain which root affected). Each of the hospitals was asked to select three representative patients for each indication (9 patients in total), to perform the examinations according to normal practice, and to present the images from the examinations on film. Staff from the radioprotection authority met at the hospital with two experienced CT radiologists and one CT radiographer (and a hospital physicist if present). The two local radiologists were evaluating the images in consensus, following the schemes in EUR 16262EN Appendix II [3].The radiographic technique for each of the patients was recorded with assistance of the CT radiographer (EUR 16262EN Appendix I). The $CTDI_w$ and DLP values were calculated from the exposure parameters using the nominal CTDI values for the respective scanners, using infomration from the Impact group, St. Georges' Hospital , London (http://www.sghphy.demon.co.uk/index.htm). If $CTDI_w$ and DLP values were provided on the CT monitor, compliance was checked by comparison with the calculated values. From EUR 16262EN Table 2 (page 67) the effective dose from the examination was assessed. Some countries also used conversion factors provided by the National Radiological Protection Board (NRPB) in UK [6]. The software called CTDOSE (Heron Le JC, National Radiation Laboratory, Christchurch, New Zealand), and the scanner matching data from the Impact group, were then used to calculate the effective dose and some organ doses (lenses, gonades). Totally 3x3x5=45 images were evaluated in each country, with corresponding dose calculations.

3. Results

The distribution of CT scanners in the survey is given in Table I, illustrating the introduction of helical scanners in the Nordic countries during the last decade [x, x].

Table I: The CT scanners in the survey

Manufacturer	Number of various CT scanner models
Elscint, Picker	
General electric	
Picker	
Toshiba	

Say something about the radiographic technique in comparison with the quality criteria, something about the window settings, and the use of contrast. Refer to table II, III and IV for the dose.

Table II: Dose figures CT of the brain

	Denmark	Finland	Iceland	Norway	Sweden	EU reference value
$CTDI_w$ (mGy)						
DLP(mGy·cm)						
D_{lenses} (mGy)						
E (mSv)						

Table IV: Dose figures CT of the lumbar spine

	Denmark	Finland	Iceland	Norway	Sweden	EU reference value
$CTDI_w$ (mGy)						
DLP(mGy·cm)						
$D_{gonades}$ (mGy)						
E (mSv)						

Figures: Three histograms, one for each examination type, counting the number of criteria fulfilled in each country. Or tables like the table below

Table V: The fulfilments of the EU image quality criteria for CT of the brain

	DE	FI	IS	NO	SW	Total
Visualisation of 1. Whole cerebrum						
2. Whole cerebellum						
3. Whole skull base						
4. Vessel after intravenous contrast media						
Critical reproduction Visually sharp reproduction of the …						
1. - border between white and grey matter						
2. - basal ganglia						
3. - ventricular system						
4. - cerebrospinal fluid space around the mesencephalon						
5. - cerebrospinal fluid space over the brain						
6. - great vessels and the choroids plexuses after intravenous contrast media						

etc...

4. Discussion and conclusion

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DOSIS EN EXAMENES RADIOGRAFICOS Y LOS NIVELES ORIENTATIVOS

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SUMMARY

This work shows a study done on conventional radiodiagnostic equipment.

The evaluation was implemented throughout different areas of Bolivia, covering not only single equipment radiographs used in the cities, but also the ones used in rural areas.

There have been more than 90 equipment pieces evaluated of which the dose received by a patient for a given exam, has been considered an essential element.

For this purpose two types of examinations have been selected, being considered the more numerous.

Not only the dose aspect was taken into consideration but the technique used as well. These elements that, that support very important information, have been related to orientative levels..

1.- INTRODUCCION.-

El uso masivo de las radiaciones producidas por los equipos de radiodiagnóstico en el área de salud hace necesario establecer ciertos marcos que vayan a delimitar el trabajo de toma de placas radiográficas. Uno de los elementos que ayudan a establecer estos criterios es la dosis, y lo que representan los niveles orientativos, que es necesario considerarlos pero teniendo presente siempre que ligados a la dosis se encuentran otros elementos tan importantes. Entre estos elementos podemos citar, la técnica empleada para un examen dado, la calidad de la imagen que redundara en un interpretación acertada o no, el equipo radiográfico mismo con una serie de parámetros que deben ser considerados, sistema de revelado, etc. Si tomamos en cuenta todos los aspectos que involucran la obtención de la imagen radiográfica observaremos que la combinación de todos los factores hacen muy difícil establecer metodologías estándares, que permitan obtener una buena calidad radiográfica con dosis bajas.

Por lo anterior en el presente trabajo se ha buscado relacionar dos elementos, como ser la técnica usada y la dosis, y compararlos con los niveles orientativos.

2.- MATERIALES.-

Para el trabajo se utilizaron los siguientes materiales:

- Medidor de tensión, no invasivo, con el propósito de establecer el valor real del kilovoltaje aplicado en el examen.
- Medidor de tiempo, para establecer el tiempo real de irradiación.
- Cristales de Fli
- Lector de cristales termoluminiscente

3.- METODOLOGÍA.-

Se han recogido información de 96 equipos de radiodiagnóstico tomando dato s de la técnica empleada, asimismo evaluando los parámetros principales señalados, además de otros como por ejemplo capa hemirreductora, coincidencias de campo y haz luminoso, precisión del medidor de distancia, sistema de revelado, tipo de placas, estado de los chasis, etc.

Además se ha tomado mediante los cristales, las dosis que reciben los pacientes. Existen también otros elementos como ser volumen de pacientes, placas repetidas, y hasta contextura física del paciente que también ha sido recabado como información, pero para efectos del presente trabajo no se considerara.

Con los datos obtenidos y la información proporcionada se han elaborado unos tablas y gráficos que nos permitirán comparar con los niveles orientativos.

4.- RESULTADOS.-

Variación del kilovoltaje

Rango de Variación	**Porcentaje del Total de equipos (%)**
0 kV– 5 kV	46
5 kV – 10 kV	27
10 kV – 20 kV	18
Mayor a 20 kV	9

Variación del tiempo

Diferencia Valor medido y Valor nominal (%)	**Porcentaje del Total de equipos (%)**
Menor al 5 %	31
Entre 5% y 10 %	18
Entre 10% y 20%	23
Mayor a 20%	28

Para comparar con los niveles orientativos se han considerado solo dos exámenes , tórax y abdomen.

Se han considerado los niveles orientativos indicados en las Safety Series 115 " Safety Standars for protection againt ionizing radiation and for the safety of sources" del Organismo Internacional de Energía Atómica, del Anexo II.

NIVEL ORIENTATIVO PARA TORAX
(0.4 mGy).

Rango	**Porcentaje de equipos (%)**
Menor o igual a 0.4 mGy	19
Entre 0.4 y 1 mGy	31
Entre 1.0 y 2.0 mGy	21
Mayor a 2 mGy	29

NIVEL ORIENTATIVO PARA ABDOMEN
(10.0 mGy).

Rango	**Porcentaje de equipos (%)**
Menor o igual a 10.0 mGy	78
Entre 10.0 y 20.0 mGy	13
Mayor a 20.0 mGy	9

5.- CONCLUSIONES.-

- En el estudio solo se han considerado las variables kilovoltaje y tiempo, y no se ha considerado la intensidad de corriente, que es otro elemento que determina la dosis recibida por el paciente en el exámenes. radiográfico.
- Solo considerando el factor tensión tendremos que menos de la mitad de los equipos evaluados se encuentran en buenas condiciones, ya que el kilovoltaje que proporcionan los equipos es similar al que indican el panel.
- En lo que respecta al tiempo, también podemos indicar que casi la mitad de los equipos radiográficos evaluados pueden considerarse en condiciones adecuadas.
- Efectuando la relación de estos parámetros con los niveles orientativos implicaría que la mitad de los equipos dan niveles de radiación similares a los niveles orientativos.
- La anterior conclusión no es cierta ya que con valores muy por debajo de los niveles orientativos, no encontramos con placas subexpuestas, que desde el punto de calidad de imagen, no será el requerido.
- Para efectuar una análisis completo no solo es necesario tener en cuenta la dosis, será preciso considerar como el elemento mas importante la calidad de la imagen.

- Será importante relacionar los parámetros de funcionamiento del equipo, sistema de revelado, técnica usada, con la calidad de imagen y dosis, para así contar con una valoración mas completa.

ESTIMACION DE DOSIS A PACIENTES EN PROCEDIMIENTOS DE ABLACION POR RADIOFRECUENCIA: COMPARACION ENTRE LA DOSIMETRIA POR TERMOLUMINISCENCIA Y LAS MEDIDAS CON CAMARA DE TRANSMISION

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ABSTRACT

Radiofrequency catheter ablation is an effective option to treat life-threatening arrhytmias. Among the risks of this type of procedures are the high radiation doses to patients. The major concern for monitoring of doses has been related to skin damage. Skin dose can be measured directly with thermoluminiscence dosimeters (TLDs) or can be determined from the dose-area product (DAP). In this work these two different methods are discussed. The radiation doses have been estimated in more than 20 patients with the two types of monitoring. In order to find the location of the maximum dose from the procedure with TLDs, dosimeter arrays can be placed on the patient. Unfortunately TLDs do not allow immediate feedback to the fluoroscopist. They require a fair amount of handling, calibrating, processing and annealing. On the other hand, the DAP provides immediate feedback of the cumulative dose. To obtain the skin dose from DAP the area of the radiation field on the skin must be determined, and it is necessary to correct the result by a factor that includes the variation of geometry during the procedure. Nevertheless these and other factors can lead to significant errors in dose estimation.

1. INTRODUCCION

La ablación con radiofrecuencia es una alternativa efectiva a la terapia médica para pacientes con arritmias [1]. A pesar de ello es una técnica que presenta sus riesgos entre los que se encuentran las altas dosis de radiación recibidas por el paciente, que pueden alcanzar el umbral de los efectos deterministas y producir eritema e incluso radiodermitis en la zona del paciente directamente expuesta al haz de radiación [2]. Este es un aspecto que exige atención desde el punto de vista de protección radiológica y que tiene obvias implicaciones clínicas.

Para prever el alcance del posible daño producido por la radiación es necesario medir las dosis recibidas por los pacientes. Uno de los métodos más simples consiste en calcularlas a partir de medidas de rendimiento o de la tasa de dosis del equipo de rayos X, teniendo en cuenta el tiempo total de fluoroscopia utilizada. Sin embargo este método está sujeto a fuentes de error considerables, ya que tanto la geometría como los valores de tensión y corriente varían considerablemente durante la exploración. Entre los métodos alternativos se pueden destacar la medida de dosis mediante dosímetros de termoluminiscencia y la medida del producto dosis*área mediante cámaras de transmisión. El objeto de este trabajo es intentar comparar estos dos últimos métodos para desarrollar procedimientos razonablemente sencillos y fiables de estimación de la dosis que reciben los pacientes.

2. MATERIAL Y METODOS

Se han realizado medidas sobre un grupo de más de 20 pacientes que han sido sometidos a procedimientos terapéuticos de ablación en el laboratorio de electrofisiología cardiaca del Hospital Universitario de Valladolid (España) [3]. Para estimar las dosis recibidas por los pacientes se han utilizado simultáneamente dosímetros TLD-100 y las lecturas recibidas por una cámara de transmisión. Para intentar obtener el punto en la piel que recibe mayor cantidad de dosis se ha colocado en la espalda de cada paciente dos filas de 10 dosímetros cada una, con una separación de 2

cm entre ellas. Dentro de cada tira la distancia entre dosímetros también es de 2 cm. Los dosímetros se leyeron en un equipo Victoreen 2800M siguiendo los procedimientos descritos en la referencia [4].

Como cámara de transmisión se ha utilizado una cámara PTW Diamentor M2 colocada a la salida del tubo de rayos X. Por último y para obtener una idea de los campos de radiación utilizados a lo largo del procedimiento se ha colocado para cada paciente una placa radiográfica lenta (Kodak X-Omat V) en la superficie de la mesa de intervención.

3. RESULTADOS

En función de las características de cada procedimiento se han obtenido valores distintos de tiempo de fluoroscopia, tensión y corriente. Los tiempos son habitualmente grandes y pueden llegar a superar de manera no demasiado infrecuente las 2 horas, con un valor medio superior a la hora de fluoroscopia. Además cuando se trata de pacientes gruesos el sistema de imagen requiere un haz de radiación con tensiones superiores a 90 kV y corrientes de más de 3 mA.

3.1. DOSIMETRIA DE TERMOLUMINISCENCIA

En la figura 1 se muestran los valores máximos de dosis registrados en los dosímetros colocados en la espalda del paciente y los tiempos de fluoroscopia para la misma muestra de pacientes. Los valores de dosis son siempre altos (en ocasiones y en puntos concretos de la piel han superado 4 Gy), aunque variables entre pacientes debido a la particularidad de cada exploración, y dentro de la tira entre dosímetros debido a que cada uno de ellos está un tiempo distinto dentro del haz directo de radiación. Para ilustrar este último comentario en la figura 2 se muestran los resultados típicos de una tira de 20 dosímetros. A pesar de las precauciones tomadas, no puede garantizarse que el punto de la piel del paciente que ha recibido la máxima dosis haya quedado registrado dentro la lectura de los veinte dosímetros.

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3.2. CAMARA DE TRANSMISION

La cámara de transmisión presenta los resultados en forma de producto dosis*área. Para el cálculo de la dosis en la espalda del paciente a partir de dicho valor puede utilizarse la siguiente expresión:

$$D_{in} = \frac{F(p,T) * F_r * F_t}{S} * L$$

donde D_{in} es la dosis a la entrada de la superficie del paciente, $F(p,T)$ es el factor de corrección por presión y temperatura, F_r es el factor de retrodispersión, F_t es el factor de transmisión de la mesa radiológica, S es el área irradiada en la espalda del paciente y L es la lectura de la cámara. Todos los factores pueden ser evaluados con lo que en definitiva D_{in} puede ser calculada como el producto de un factor por la medida de la cámara. En la tabla 1 se resumen los resultados obtenidos. La variabilidad en los mismos puede explicarse en función de los distintos tiempos de fluoroscopia utilizados, de los parámetros geométricos y de las características de espesor de los pacientes.

	Mínimo	Mediana	Media	Máximo
Parámetros haz radiación				
Tensión (kV)	64	73	76	96
Intensidad (mA)	1.6	2.0	2.2	3.4
Tiempo escopia (min)	20	63.3	73.2	139.1
Medida con TLD				
Máximo de dosis (Gy)	0.3	0.9	1.5	4.7
Abdomen (mGy)	0.5	1.5	1.9	4.5
Frente (mGy)	< 0.01	0.15	0.25	0.76
Medida con Diamentor				
Dosis*área (cGy/cm2)	5600	23400	25700	77000
Dosis máxima calculada (Gy)	0.41	1.25	1.8	5.61

Figure 1 Datos estadísticos correspondientes al haz de rayos X y a las medidas con TLD y cámara de transmisión

En condiciones ideales, si la geometría no se hubiera modificado durante un procedimiento, la lectura proporcionada por la cámara debería coincidir con la dosis máxima de la tira de dosímetros. Sin embargo dada la variabilidad de la misma no es el mismo punto de la espalda del paciente el que recibe la máxima dosis por lo que la medida del Diamentor tiende a sobrestimarla en un valor próximo, según estos cálculos, al 30%, aunque en algunos casos han llegado a ser del 50%. Estas variaciones pueden ser debidas a que no se ha conseguido registrar el punto de mayor dosis en el paciente dentro de la superficie registrada por la tira de dosímetros.

4. DISCUSION

Aunque la radiación puede producir efectos estocásticos y deterministas, en este caso son estos últimos los que adquieren una gran importancia debido por una parte a las altas dosis de radiación recibidas por los pacientes y por otra a que el grupo de población que es sometido a este tipo de procedimientos es relativamente pequeño si se compara con otro tipo de exploraciones de radiodiagnóstico. Aunque pueda haber órganos que tengan riesgo de alcanzar los efectos deterministas, la mayor preocupación a la hora de evaluar las dosis está en el daño sufrido por la piel [5]. Más aún, una vez que se conoce la dosis a la entrada hay distintos métodos para determinar la dosis a órganos internos [6]. En este trabajo se han utilizado dos métodos distintos de obtener la dosis máxima en la piel de los pacientes sometidos a ablación por radiofrecuencia.

La mayor dificultad en la dosimetría con TLD's está en garantizar una correcta colocación de los mismos en la espalda del paciente para asegurar que el punto de la piel que recibe mayor dosis puede quedar registrado con la lectura de los dosímetros irradiados. Obviamente para soslayar esta dificultad puede recurrirse a una matriz más compacta (con menos distancia entre dosímetros) y bidimensional [7]. Con todo uno de los mayores problemas del método es su laboriosidad que lo puede hacer poco recomendable para un uso sistemático. Además los valores obtenidos no pueden verse durante el desarrollo de la exploración, sino que requiere una lectura y limpieza en un laboratorio. Los dosímetros utilizados habitualmente para dosimetría de pacientes son los de fluoruro de litio que presentan una variación en su respuesta con la energía de un 30% - 40% desde 30 keV hasta 100 keV. Además las dosis en estos procedimientos pueden alcanzar el rango en el que la respuesta del TLD se convierte en supralineal (en torno a 6 Gy), lo que obligaría a utilizar necesariamente factores de corrección.

La utilización de una cámara de transmisión tiene inicialmente la ventaja de que los valores medidos se presentan en tiempo real en pantalla con lo que el cardiólogo puede tener una idea de la cantidad de dosis que está recibiendo el paciente. Sin embargo a diferencia de los TLD la medida de dosis en la piel se convierte en indirecta y es necesario estimar el área del haz de radiación. Una incertidumbre de un 5% en la medida de las distancias se traduce en una incertidumbre del 10% en el valor del área. Además no debe olvidarse que dicho área cambia con la orientación de la geometría, con el modo de magnificación usado y con el ajuste de los colimadores. Por otra parte debe aceptarse la inclusión de

un factor de corrección que tenga en cuenta la variación del campo de entrada a lo largo del procedimiento.

También el resto de factores presentes en el cálculo presentan una incertidumbre. El factor de retrodispersión depende del tamaño de campo del haz de radiación y de la energía pero su variación puede estar acotada en un 10% de su valor medio para el intervalo de campos y energías utilizados en este tipo de exploraciones [8]. El factor de transmisión de la mesa radiológica depende de la energía pero también del ángulo de incidencia del haz de radiación. Por último si el colimador dispone de filtros compensadores, la utilización de los mismos subestimará la medida de la dosis en las zonas no atenuadas por los mismos mediante el método de cámara de transmisión.

5. CONCLUSION

Los dos métodos estudiados de estimación de dosis a pacientes en procedimientos de ablación por radiofrecuencia presentan ventajas e inconvenientes que los pueden hacer más o menos recomendables en función del objetivo que se tenga en mente. En este tipo de procedimientos con tan altas dosis puede ser necesario un conocimiento más preciso de las mismas para establecer criterios de vigilancia y actuación específicas para aquellos casos en que se superen determinados niveles. La medida directa con una matriz bidimensional de TLD's suficientemente compacta parece ser la respuesta a esta necesidad ya que es el método que presenta menor grado de error, aunque sea poco práctico. Sin embargo también puede ser muy interesante para el cardiólogo tener en tiempo real la dosis recibida por el paciente durante una intervención para poder determinar si debe ser modificado el procedimiento para proteger la piel del paciente de daños debidos a la radiación. La medida de tiempos de fluoroscopia y parámetros del haz de rayos X (tensión y corriente) puede dar aproximaciones adecuadas, aunque con un margen de error que puede ser muy importante.

Si se está dispuesto a asumir un cierto grado de incertidumbre (que puede ser superior al 30% en determinados casos) en la medida de la dosis para así poder obtener las lecturas durante la intervención, el modo más simple y práctico parece la medida sistemática del producto dosis*área con una cámara de transmisión, con la inclusión de un factor de corrección que tenga en cuenta la variación del campo de entrada a lo largo del procedimiento.

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Training

EDUCATION, TRAINING AND CONTINUING PROFESSIONAL DEVELOPMENT FOR THE MEDICAL PHYSICIST – THE EFOMP VIEW IN RELATION TO EC COUNCIL DIRECTIVES

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Abstract: The European Federation of Organisations for Medical Physics, EFOMP, is an umbrella organisation for National Medical Physics Organisations. One of the main objectives of EFOMP is to harmonise and promote the best practice of Medical Physics within Europe. To accomplish this goal, EFOMP has presented various recommendations and guidelines in a number of Policy Statements, unanimously adopted by EFOMP Member Organisations. Policy Statement No 9, "Radiation Protection of the Patient in Europe: The Training of the Medical Physics Expert in Radiation Physics or Radiation Technology", is the EFOMP response to the Medical Exposure Directive, 97/43/Euratom. Here EFOMP presents its recommendations on the role and the competence requirements of the Medical Physics Expert, defined in this Directive, together with recommendations on education, training and Continuing Professional Development. The previous Directive 96/29/Euratom, the Basic Safety Standards Directive, defines a "Qualified Expert" in the radiation protection of workers and the general public. EFOMP has an on-going discussion on the interpretation of the competence requirements of the Qualified Expert in medical practice. The EFOMP approach to achieve harmonisation in the qualification of the Medical Physicist is to encourage the establishment of education and training schemes according to EFOMP recommendations.

1. Introduction

The European Federation of Organisations for Medical Physics was inaugurated in 1980 as an umbrella organisation for National Medical Physics Organisations. Today EFOMP has 32 National Member Organisations (NMOs), representing about 5000 medical physicists working in both clinical and research environments. The federal structure allows EFOMP to represent the medical physics profession, without constraining that diversity of national opinion, which is the essence of Europe.

To harmonise and promote the best practice of medical physics in Europe is one of the main objectives of EFOMP. Some specific aims and purposes include making recommendations on the appropriate general responsibilities and roles of the medical physicists and proposing guidelines for education, training and accreditation programmes in medical physics. EFOMP should also collaborate with international organisations and disseminate professional and scientific information. The EFOMP view on education and training has been presented at several international meetings, one of the latest being the International Conference on "Radiation Protection: What are the future training needs?" [1].

To accomplish its goals, EFOMP has over the years presented a number of policy statements, adopted unanimously by the NMOs, thus expressing the opinion of the medical physics profession in Europe. The first two policy statements, approved in 1983, presented the roles and responsibilities of the clinical medical physicist, discussed the important professional aspects of education and training, and established the basic structure of education and training. "The education of the medical physicist can be divided into three stages. After a first step bringing the physicist up to a basic standard (B.Sc.) in Physics, Mathematics, and other relevant topics in Natural Sciences, the second step is to introduce Medical Physics in postgraduate education. The third step is in-service training in hospitals. After finishing this third step, the physicist can be recognised at an appropriate level. It should also be possible to reach a senior level by further education and training, and to get a higher academic degree, i.e. M.Sc., Ph.D. or equivalent in Medical Physics." This structure is still relevant and has been developed in several recent policy statements.

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The clinically working medical physicist is a member of a team responsible for diagnosis and treatment of patients. The qualified medical physicist has a unique competence and is responsible in his area of competence for equipment, techniques and methods used in the clinical routine, for the introduction and adaptation of new methods, for quality assurance and quality control etc., and often also for research and development. In order to acquire and maintain sufficient knowledge and a certain level of competence, both initial and continuing education and training are necessary.

2. Education and training in Medical Radiation Physics

European legislation has challenged many professional organisations to propose harmonised professional standards of high quality. The European Union's Directives concerning basic safety standards [2] and medical exposures [3] have given impetus to the discussions of education and training requirements in medical physics. From the EFOMP view these Directives primarily deal with medical *radiation* physics, but they also effectively set the standards for the whole medical physics profession.

The EFOMP policy statement No 9, "Radiation Protection of the Patient in Europe: The Training of the Medical Physics Expert in Radiation Physics or Radiation Technology" [4], constitutes the EFOMP response to the Medical Exposure Directive, 97/43/Euratom, [3], the MED. The Medical Physics Expert (MPE) is defined in this Directive as an expert in his own right with a well-defined professional role, requiring him to act as well as give advice on all aspects of radiation protection of the patient. The training of the MPE and his competence to act must be recognised by the competent authorities, and Member States are explicitly required to ensure that medical physicists have access to continuing education and training after qualification in addition to their basic theoretical and practical training.

The EFOMP recommendations on the role and competence requirements of the Medical Physics Expert are presented in policy statement No 9 [4], together with the recommendations on principles of education, training and continuing professional development (CPD). General criteria for structured CPD have been laid down in policy statement No 8, "Continuing Professional Development for the medical Physicist" [5]. CPD is the planned acquisition of knowledge, experience and skills, both technical and personal, required for professional practice throughout one's working life. EFOMP recommends that all medical physicists who have completed their basic education and training should be actively involved in CPD to maintain and increase competence and expertise after qualification.

The EFOMP approach to achieve harmonisation is to encourage the establishment of national education and training schemes at all levels according to EFOMP recommendations. Guidelines for formal EFOMP recognition of National Registration Schemes for Medical Physicists were established in 1995 [6]. EFOMP approval requires inter alia clear statements of theoretical and practical competencies, as well as training programmes consistent with the EFOMP policy on training, and a regular renewal mechanism. CPD is now being recommended as the best way to meet the requirement for a renewal mechanism, and EFOMP is now finalising general guidelines for CPD Schemes [7], recommending NMOs to set up their own detailed CPD Scheme. The concept of CPD is related to the knowledge, skill and experience acquired rather than to the amount of time used to require them. In practice, however, quantitative and qualitative guidelines cannot be separated. The general and very flexible guidelines proposed for CPD Schemes cover both the scheme itself and the credit point system for assessment of individual CPD activities. EFOMP approval also of the National CPD scheme will thus cover the whole structure of education and training for the medical physicist.

The EFOMP efforts, resulting in recommendations on a structured system for education training, CPD and registration schemes as outlined above, have been recognised by the EC in the recent publication "Guidelines on education and training in radiation protection for medical exposures" [8].

3. Training of the Medical Physics Expert – the Specialist Medical Physicist

The Medical Physics Expert was introduced and defined in the Medical Exposure Directive. The duties of the MPE, specified in the Directive, suggest that the appropriate competence level should correspond to an advanced practical experience. The competence level required to start working independently is the level required to register as a Qualified Medical Physicist, according to the EFOMP recommendations [4, 6]. CPD activities should start immediately after qualification, ensuring increasing competence and leading to a higher level of qualification, e.g. the level where the medical physicist may act as a Medical Physics Expert. The EFOMP approach to structured education, training and CPD, as recommended in the proposed guidelines on CPD schemes [7], is summarised below.

The Qualified Medical Physicist:

- There is a significant divergence across European in the length and style of the academic component of physics qualifications. However, most countries will be able to recognise the Qualified Medical Physicist defined in the guidelines below.
- The entry criterion to Medical Physics education and training is a basic university education in physical sciences, engineering or equivalent.
- Recognition as a Qualified Medical Physicist is achieved by a further 2 to 4 years theoretical education and practical training in Medical Physics (depending on the national education system) under supervision of a Qualified Medical Physicist, preferably a Specialist Medical Physicist. At least half of the time should be spent in a clinical environment. The education and training should follow current EFOMP policies. (The total time for the basic education and the Medical Physics education and training would be around 7 years.)
- The Qualified Medical Physicist is competent to act independently.
- The Qualified Medical Physicist has the minimum qualifications required for enrolment in an EFOMP approved National Register for Medical Physicists.
- The Qualified Medical Physicist should have a formal recognition from a National Competent Authority, and should be enrolled in an EFOMP approved National Register for Medical Physicists [6].

The Specialist Medical Physicist, the Medical Physics Expert:

- Within the EU, as defined in the Medical Exposure Directive [3] "in relation to medical exposure", the Medical Physics Expert is equivalent to the Specialist Medical Physicist. In other disciplines, the term Medical Physics Expert is not relevant.
- The Qualified Medical Physicist qualifies to become a Specialist Medical Physicist by gaining advanced clinical experience and undergoing specialist training of at least two further years duration, mostly in one sub-speciality, within the first period of an EFOMP approved National CPD Scheme. (i.e. total education & training at least 9 years)
- The Specialist Medical Physicist is competent to give advice on all professional matters in his sub-speciality.
- The Specialist Medical Physicist may have a formal recognition from a National Competent Authority and should continue to be enrolled in an EFOMP approved National Register for Medical Physicists.

4. The Medical Physics Expert and the Qualified Expert in medical applications

The MED "supplements Directive 96/29/Euratom and lays down the general principles of the radiation protection of individuals in relation to the exposure referred to in paragraphs 2 and 3." [3, Art 1.1]. The MPE is defined as "an expert in radiation physics ... acts or gives advice on patient dosimetry, on the development and use of complex techniques and equipment, on optimization, on quality assurance, including quality control, and on other matters relating to radiation protection, concerning exposure within the scope of this Directive" [3, Art 2]. The Basic Safety Standards Directive 96/29/Euratom (BSS) "establishes the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation with the aim of their uniform implementation by Member States" [2, Art 54]. The BSS defines Qualified Experts (QEs), as "Persons having the knowledge and training needed to carry out physical, technical or

radiochemical tests enabling doses to be assessed, and to give advice in order to ensure effective protection of individuals and the correct operation of protective equipment, and whose capacity to act as a qualified expert is recognised by the competent authorities" [2, Art 1]. The BSS also states, that Member States shall ensure that training of the QEs is arranged. Both the BSS and the MED should have been transposed into national law no later than 13 May 2000.

The EC "Guidelines on education and training for medical exposures" [8] were written to facilitate implementation of the MED. "Adequate theoretical and practical training for the purpose of radiological practices, as well as relevant competence in radiation protection" is required in the MED, [3, Art 7.1], and the training programmes in the guidelines thus include both general principles of radiation protection and particular staff aspects; "MPEs should know all the training areas at the highest level in addition to physics and all relevant aspects of quality assurance programmes.", according to the Guidelines [8, 1.(24)]. In the "Communication from the Commission concerning the implementation of Council Directive 96/29/Euratom" [9], advice on basic and additional training for QEs is given in Annex I. The requirements on education and training, as well as on the appropriate practical experience, will depend on the complexity of the field of work and on the level and complexity of advice required from the QE; medical applications is one of the five specific areas, where additional topics have been identified. The MPE acts within the scope of the MED, the QE within the scope of the BSS. EFOMP has an on-going discussion on the interpretation of these recommendations relative to medical practice, concerning the role and responsibilities of the MPE. The MPE should be prepared to assume the responsibilities of the QE, but, in health care centres with MPEs available should the MPE and no one else take the responsibilities of the QE, and further, should the QE be required to have the competence of the MPE? The present situation in Europe shows a wide variation in the qualification requirements of the QE in medical practice.

5. Summary

The responsibilities of the Medical Physics Expert defines his competence, and EFOMP wants to emphasise that the term MPE should apply only to suitably experienced medical physicists, with a competence based on a structured education and training programme including CPD. EFOMP has presented policy statements related to all parts of this programme, in order to accomplish one of its main objectives; to harmonise and promote the best practice in medical physics in Europe.

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COMPARACIÓN DE DOS MATERIALES PARA LA CONFORMACIÓN EN RADIOTERAPIA

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Introduction Treatment of Hodgkin disease involves shielding blocks. It is necessary to evaluate them when material employed is new or blocks aren't manufactured at centre.

Purpose. To compare dose distribution produced by different materials. To evaluate dose outside field for several distances and deeps. To assess a method to manufacture blocks.

Material and methods. We have studied a mantle field with shielding blocks of two materials, low melting points and lead. We have measured, with a water phantom, at several deeps and we have analysed the penumbra at several sites. Also, we have measured dose outside field irradiation at several distances and deeps to estimate dose at organs at risk.

Results. In penumbra, differences are in range of 0.8-2.7 mm for 6 MV and 0-3.9 mm for 18 MV always larger for lead. Dose outside field differences versus deeps are clear, but minor, for 6 MV when we fix the distances. Dose versus distances for a deep, are similar.

Conclusions. It is essential to assess all modifications to daily procedures as room moulds outsourcing and new material use. In this case, differences, in penumbra and dose outside field, are minor but it is necessary to consider them for some patients.

1.- Introducción.

La utilización de conformaciones personalizadas en bastantes tratamientos, entre ellos el linfoma de Hodgkin, es una práctica frecuente en los Servicios de Radioterapia[1]. Estos bloques están, normalmente, fabricados en material de bajo punto de fusión[2]. En algunos casos, puede ser necesaria su fabricación en otros materiales como plomo. Además de la adecuación del bloque a lo prescrito en la placa de simulación[3], es necesario entonces estudiar el comportamiento de las protecciones realizadas en cuanto a la producción de penumbra y protección de los órganos de riesgo. También es conveniente comparar ambos materiales en cuanto a radiación dispersa en aquellos puntos, que estando fuera del campo de radiación, puedan ser calificados como órganos de riesgo.

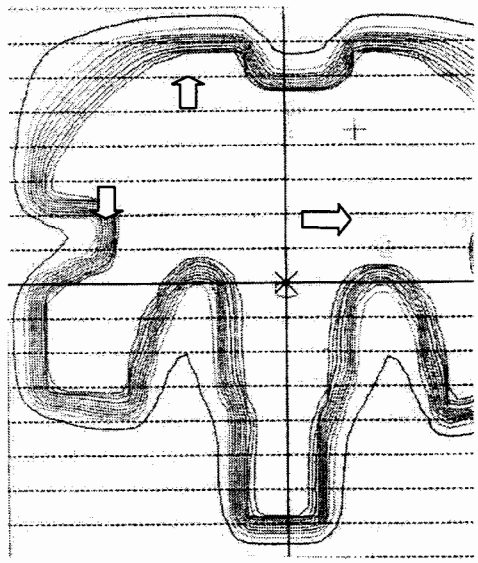
Cuando el servicio está externalizado, es una verificación inicial de la adecuación del mismo a las tolerancias del centro.

2.- Objetivos.

Estudiar un material distinto del utilizado normalmente para conformar los campos de radiación. Comparar la distribución de dosis producida por dos tipos de material utilizado en conformación de campos. Estimar la dosis dispersa existente para estos dos tipos de aleación a distintas distancias del campo de radiación y distintas profundidades. Verificar, inicialmente, una nueva técnica de preparación de los bloques de conformación.

3.- Material y métodos.

Se estudian dos campos conformados reales correspondientes al tratamiento de linfoma de hodgkin. Los campos son del tipo mantle. La conformación se ha realizado con aleación de bajo punto de fusión y otra aleación compuesta, fundamentalmente, de plomo. El espesor de los bloques de aleación es de 8 cm y los de plomo 7, basados en medidas anteriores[4]. Todos los bloques son focalizados.



En los dos casos se han realizado medidas de la distribución de dosis, mediante sistema ionométrico, a distintas profundidades, en el máximo para cada energía y en isocentro, 10 cm, y para las dos energías de un acelerador lineal, 06 MV (J100/J200 = 1.73) y 18 MV (J100/J200 = 1.52). De esta distribución se ha medido la anchura de la penumbra en las protecciones de varios órganos (figura I): pulmón, cabeza humeral y boca

También se ha estimado, con cámara de ionización, la dosis dispersa para los dos tipos de aleación, las dos energías y a distancias del límite de campo y profundidades, compatibles con la posición de las gónadas de la paciente. Para ello se ha empleado un espesor de PMMA de 20 cm, compatible con el diámetro antero-posterior de la paciente para la que se fabricaron las conformaciones. Para alojar la cámara, también se ha empleado el mismo materia.

4.- Resultados.

4.1.- Distribución de dosis

A continuación se detallan los valores medidos para 06 MV, tabla I, y para 18 MV, tabla II.

Tabla I: Valores de la penumbra, en mm, para la profundidad del máximo y en el isocentro y en distintas localizaciones para 06 MV

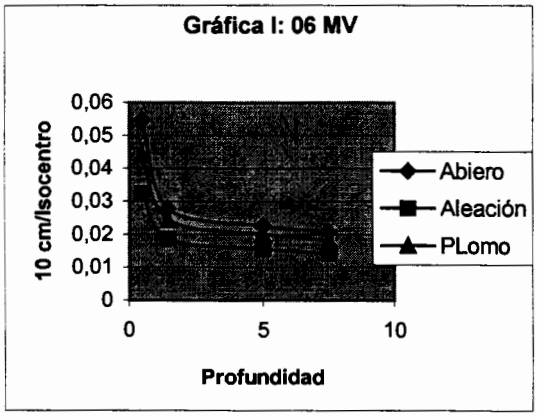
Prof.	1.5 cm			10 cm		
Material	Pulmón	Cab. Hum.	Boca	Pulmón	Cab. Hum	Boca
Aleación	12.9	11.4	11.1	31.5	20.5	19.5
Pb	13.8	14.1	12.3	30.7	22.8	18

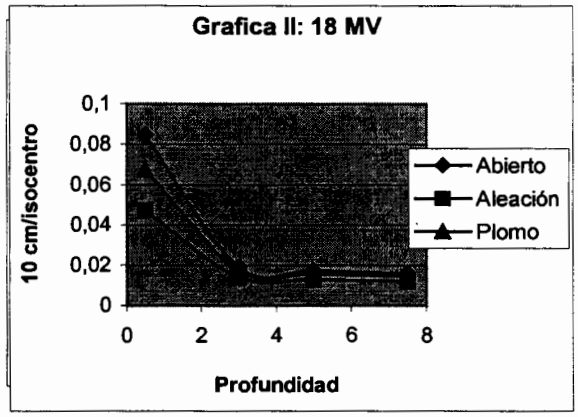
Tabla II: Valores de la penumbra, en mm, para la profundidad del máximo y en el isocentro y en distintas localizaciones para 18 MV

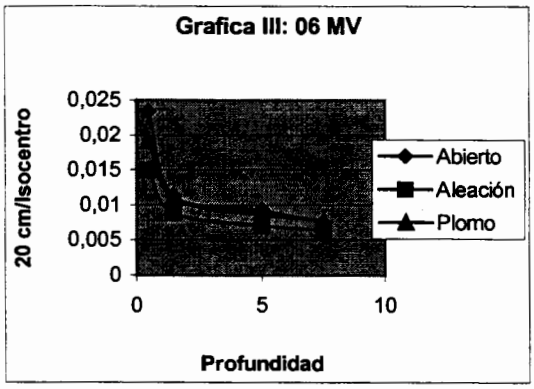
Prof.	1.5 cm			10 cm		
Material	Pulmón	Cab. Hum.	Boca	Pulmón	Cab. Hum	Boca
Aleación	15.3	14.4	12.4	19.8	16.2	16.5
Pb	15.3	14.4	15.9	19.8	20.1	16.5

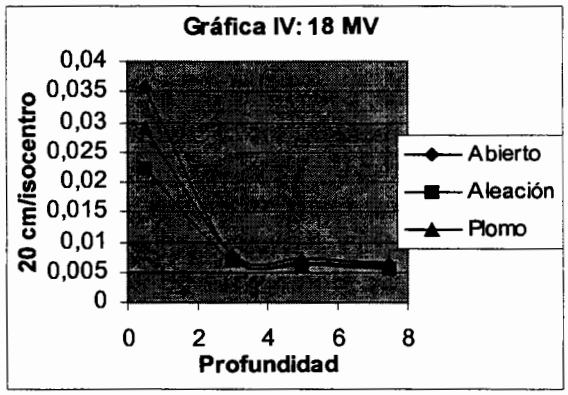
4.2.- Estimación de la radiación dispersa.

Se presentan en las siguientes gráficas los resultados obtenidos. Se representa la relación entre la dosis a una distancia del límite de campo para distintas profundidades y la dosis en el isocentro. En las gráficas I (06 MV) y II (18 MV) se representa esta relación para una distancia al borde de campo de 10 cm. En las gráficas III y IV la distancia al límite de campo es de 15 cm.

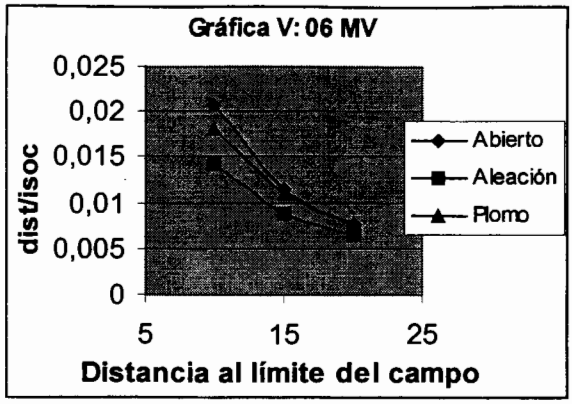


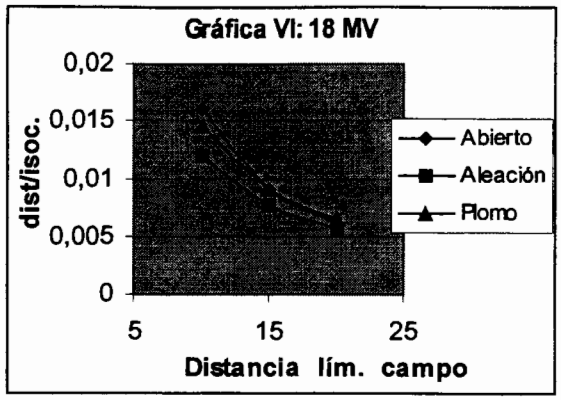






En las siguientes gráficas se representan los resultados de la misma relación (dosis en puntos fuera del campo y dosis en el isocentro) en función de la distancia al límite de campo y a 7.5 cm, aproximadamente a mitad de espesor en el paciente. En la gráfica V se exponen los resultados para 06 MV y en la VI, para 18 MV.





Para una dosis de 36 Gy y si se emplean 06 MV, esto supondría, según estas medidas, que en el punto se reciben en función de la distancia al límite de campo y la profundidad considerada entre 22 y 50 cGy para aleación, y 23 y 61 cGy para plomo. Para 18 MV los valores oscilan entre 23 y 67 cGy para aleación y 28 y 88 cGy para plomo.

5.- Conclusiones.

En el presente trabajo se ha pretendido comparar dos técnicas distintas para elaborar conformaciones de campos en radioterapia. Cada técnica lleva implícita la utilización de un material distinto y una de las técnicas no se lleva a cabo en el centro, sino que el servicio está externalizado. En concreto, hemos evaluado las diferencias en cuanto a producción de penumbra y producción de radiación dispersa en uno de los órganos críticos fuera del campo de radiación.

Por lo que se refiere a la penumbra los valores encontrados son muy similares para las dos energías utilizadas y los dos materiales analizados. Las diferencias observadas pueden ser debidas a variaciones en la fabricación. En cualquier caso son más elevadas para los bloques realizados con la aleación de plomo.

Evidentemente, en las medidas realizadas pueden influir las condiciones de medida empleadas, como pueden ser el tamaño de la cámara de ionización, la distancia entre puntos de medida, etc. Posteriores investigaciones podrían matizar los resultados que hemos encontrado. También podrían ser mejoradas si se perfeccionase el sistema de elaboración de estas conformaciones con el nuevo material.

La radiación dispersa estimada para el órgano de riesgo seleccionado es mayor para los boques de plomo para 06 MV y es equivalente para 18 MV en función de la profundidad. En función de la distancia es más favorable para la aleación tradicional para las dos energías. Aunque, en cualquiera de los casos presenta valores bajos, según estas medidas están alrededor del 1-2 % de la dosis en el isocentro, es necesario tenerlo en cuenta en algunos casos. Esta estimación también podría perfeccionarse con otros métodos de medida como TLD.

Siempre que se pone en marcha una técnica o se pretende modificar una existente es necesario evaluar los efectos que pueden tener desde el punto de vista de la protección radiológica del paciente.

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Braquiterapia

Protección radiológica del paciente en braquiterapia epiescleral

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Introduction. Choroidal melanoma and other ophthalmic tumors are treated with episcleral plaques. Optimisation and other criteria are necessary to avoid damage in eye and visual function preservation.

Purpose. To study the dosimetric phases to apply radiation protection criteria. To determine procedures for quality assurance of applicators, sources and treatment prescription and planification

Method. We have revised treatment procedure. First, aspects shared for all the patients. Then treatment planification and applicator assembling. After that, we study insertion and treatment. Finally, we check the chart flow to modify, if necessary. It necessary consider normative and recommendations.

Results and conclusions. Quality assurance of sources (calibration, autoradiography), applicator (effects, dose distribution) and treatment planning are revised. Appropriate patient data acquisition is essential due the special characteristics of tumor and eye. Treatment planning involves optimisation as a factor. Seed selection is very important to avoid misadministration. Next procedure is applicator assembling. We must car to choose the same as dosimetry and to carry out its verification. Sources insertion is a surgical procedure. It is essential an accurate placement. Desinsertion is also surgical, and must be adapted to dosimetry and prescription. Flow chart is modified adding two staff meeting to discuss about patient data and doses.

1.- Introducción.

La braquiterapia epiescleral es una alternativa a la enucleación o extirpación del ojo afecto en el melanoma uveal, el hemangioma circunscrito de coroides, el retinoblastoma o la degeneración macular asociada a la edad. Como en todo tratamiento radioterápico, los objetivos del tratamiento son suministrar la dosis prescrita minimizando en lo posible los efectos secundarios. En el caso que nos ocupa, al evitar los efectos secundarios podemos preservar el órgano, y más aún preservar la función visual[1,2,3].

En el caso de estos tumores, el problema es mayor porque el melanoma es un tumor tradicionalmente considerado como radiorresistente, con lo que las dosis suministradas son mayores que en otros tratamientos, y el angioma es un tumor benigno, por lo que cualquier irradiación debe estar muy justificada. Además, en este caso, el paciente tiene más tiempo de desarrollar efectos secundarios.

Los criterios de protección radiológica en estos tratamientos deben estar encaminados no sólo a tratar de forma eficaz el tumor, sino también a conseguir que el paciente siga conservando la visión.

2.- Objetivos.

Estudiar las fases de la dosimetría de la braquiterapia epiescleral, para discernir en cuáles de ellas se pueden mejorar nuestros criterios de protección radiológica del paciente. Establecer qué procedimientos son necesarios para asegurar la calidad de las fuentes, aplicadores y sistemas de cálculo empleados. Protocolizar la realización de la dosimetría clínica para conseguir el objetivo de minimar la dosis en los órganos de riesgo. Repasar el diagrama de flujo de la información y responsabilidad que se había establecido para mejorar la toma de decisiones y la circulación de la documentación.

3.- Método.

Hemos revisado el procedimiento del tratamiento de braquiterapia epiescleral en nuestro centro. Se estudian por separado parámetros comunes a todos los tratamientos como el aseguramiento de la calidad de fuentes y aplicadores, y del planificador de tratamientos.

Hemos revisado la adquisición de datos para cada paciente. Seguidamente se analiza la preparación del tratamiento, tanto la planificación como la preparación del aplicador. Después, se examina la aplicación del tratamiento tanto en la inserción, en el tiempo que el paciente tiene el aplicador puesto como en la desinserción. Finalmente, se repasa el diagrama de flujo del proceso[4] con la información recopilada anteriormente, por si fuera necesario modificarlo.

Todo el proceso ha sido observado a la luz tanto de la legislación aplicable, como de las recomendaciones nacionales[5] e internacionales[6,7].

4.- Resultados y conclusiones.

4.1.- Aseguramiento de la calidad de fuentes, aplicadores y planificador.

Las acciones en las que se debe incidir son:

Calibración de las fuentes con un detector pozo calibrado para las fuentes de I-125, en vez de la mera verificación de la intensidad en un calibrador de Medicina Nuclear. Progresivo empleo de la tasa de kerma de referencia en aire, TKRA.

La realización de radiografías y autorradiografías de las fuentes, aunque aconsejable, presenta grandes dificultades por las reducidas dimensiones de las fuentes.

Algunos autores recomiendan que, cuando se manipulen las fuentes de I-125 con pinzas u otros medios, se realice una prueba de hermeticidad, debido a su fino encapsulamiento.

El efecto del aplicador sobre la distribución de dosis debe ser incorporado, paulatinamente. Los aspectos que deben investigarse son: atenuación de la TKRA por el alojamiento acrílico de las fuentes y protección a las estructuras extraoculares por la placa metálica. Sobre la distribución de isodosis existen varios trabajos publicados con métodos de Montecarlo, ante la dificultad de realizar una verificación experimental.

4.2.- Adquisición de datos del paciente.

En braquiterapia epiescleral, este paso es más delicado, si cabe, que en otras aplicaciones. Los tumores son menores que en el resto del organismo y el órgano donde asientan estos tumores, el ojo, es también menor que el resto de los órganos huéspedes

de tumores; con lo que la distancia de los órganos críticos, en nuestro caso los más importantes, son la mácula y el nervio óptico, es del orden de unos milímetros.

El melanoma es un tumor, tradicionalmente, considerado como radiorresistente por lo que la dosis suministrada es del orden de 100 Gy, mayor que en resto de los tratamientos y el angioma es una enfermedad benigna, con lo que el paciente va a tener más tiempo de desarrollar efectos secundarios.

Por estos motivos, es necesario contar con la mayor cantidad de información disponible, proveniente de los medios de imagen como son, ecografía, angiografía, fotografía de fondo de ojo, TAC y RMN.

4.3.-Planificación del tratamiento.

Se ha descrito[8] cómo aprovechar la baja energía del I-125 para optimar la dosimetría clínica, para que los órganos de riesgo reciban la dosis más baja posible. Como estos autores, podemos aprovechar la anisotropía de las fuentes para disminuir dicha dosis, y evitar poner todas las que permite el alojamiento. No mezclamos intensidades por la forma de suministro de los lotes de fuentes.

Un aspecto importante a tener en cuenta es la edición de los lotes de fuentes, pues es imprescindible que sólo pueda seleccionarse el que está en uso realmente. Si, por error, empleáramos otro la duración del implante no sería correcta.

Hasta ahora, se realizaba un cálculo manual como comprobación del cálculo del planificador. Se diseñará una hoja de cálculo con el que el cálculo será más cómodo, y más preciso al automatizar, por ejemplo, las interpolaciones.

4.4.- Preparación del aplicador.

En esta parte del proceso hay que vigilar:

Que se emplea el aplicador fijado en la planificación.

Que se emplea el lote de fuentes adecuado.

Realizar una comprobación del aplicador de acuerdo con el procedimiento establecido.

Ensamblar el aplicador, como se ha previsto en la planificación, para preservar los órganos de riesgo. Es especialmente importante cuando algún alojamiento cuando no se han colocado todas las fuentes en el alojamiento.

Además, este proceso se ha de realizar en condiciones de esterilidad como corresponde a un proceso quirúrgico. Este requerimiento puede entorpecer la ejecución del procedimiento. Otra alternativa es esterilizar el aplicador después de su preparación, pero plantea más problemas de protección radiológica.

4.5.- Colocación del aplicador

Es una acción que tiene lugar en el quirófano, y que lleva a cabo un oftalmólogo con la información que le suministra el resto del equipo. La colocación tiene lugar, en la mayoría de las ocasiones, mediante transiluminación. En otras ocasiones, cuando la lesión no hace sombra o tiene una localización poco accesible, se puede colocar midiendo la distancia a algunas estructuras.

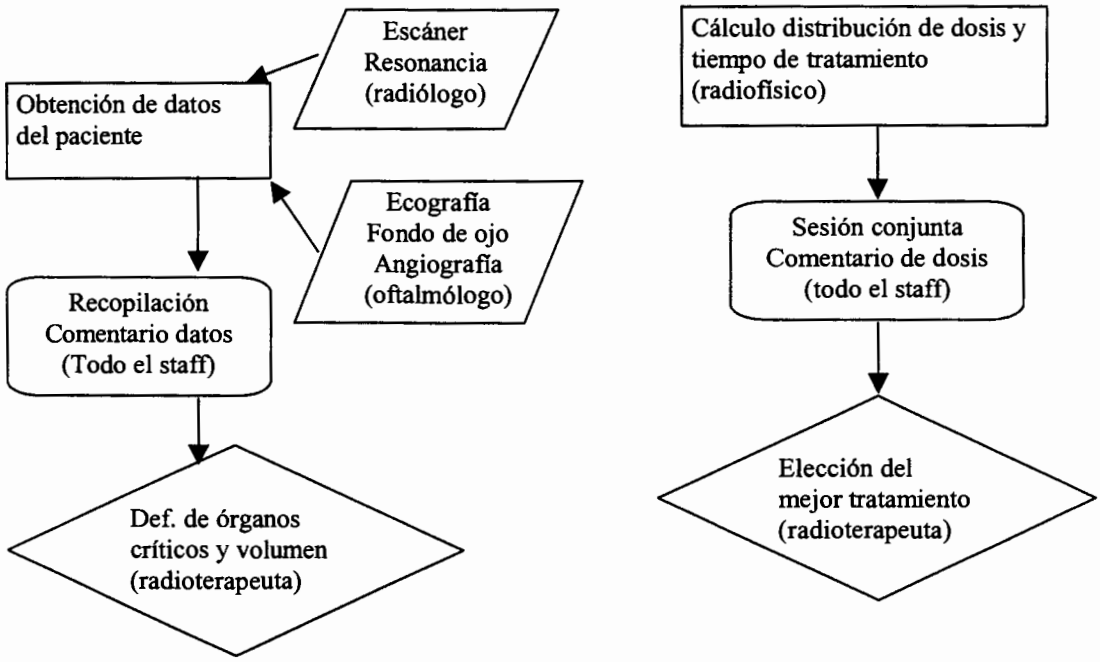
Los datos del tumor, obtenidos en fases anteriores, son los que van a dar una indicación del tamaño del aplicador. Si estos no son correctos, no podremos dejar margen de seguridad entre éste y el tumor. Además, se tiene que colocar con la orientación que marca la dosimetría para mantener la posición relativa de las fuentes respectos a los órganos de riesgo y preservar así la optimización de dosis.

4.6.- Tratamiento y desinserción.

Una vez colocado el aplicador el paciente pasa a una habitación radioprotegida en la que permanece el tiempo fijado en la dosimetría clínica. Una vez transcurrido este tiempo vuelve al quirófano para retirar las fuentes. Este segundo paso por el quirófano es especialmente programado, pues debe respetarse la duración del implante, para suministrar la dosis calculada

4.7.- Diagrama de flujo del proceso.

Se incluyen dos reuniones de todo es equipo para comentar los datos de los medios de imagen y las dosis que reciben los órganos críticos



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