Radiation Exposures in Clinical Diagnostic Studies

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The basic objective of this paper is to outline radiation doses to various critical organs of an average adult person during x-ray procedures and clinical studies in Nuclear Medicine. A comparative study is conducted to confirm clinical exposure using thermoluminescent dosimeters. Absorbed doses to critical organs are also computed. Radiation doses vary for different types of examinations and techniques. Repeats of x-ray and unnecessary clinical examinations can cause harmful effects. Biological effects of radiation for pregnant women and her fetus in early pregnancy have been discussed. To minimize radiation exposure and improve quality of image various factors have been reviewed. Routine calibration of x-ray units and implementation of effective quality assurance program can reduce the radiation exposure and achieve the optimal clinical objective.

Introduction

Radiation has an important role in medicine. Ionizing radiation is used in different imaging modalities such as digital radiology, digital subtraction angiography, computed tomography, dentistry, fluoroscopy, mammography, diagnostic x-ray and Nuclear Medicine. In addition to these, ultrasonography and magnetic resonance imaging are also of great clinical importance to diagnose any abnormality in human body. Medical radiation exposures to patients during diagnostic studies depend on various factors. In Nuclear Medicine procedures the absorbed dose depends on the amount of radioisotope being injected. In diagnostic x-ray procedures the exposure depends on Kilovoltage, milliampers, target to skin distance, field size, required projections, sex, age and thickness of the patients[1]. The dose to critical organs will be higher in the primary useful radiation beam. Radiation measurement in these procedures can assist in establishing safety guidelines for the public and the radiation workers. Presently 5 Rem* for occupationally exposed persons and 0.5 Rem for the general public have been considered as safe limits[2]. Radiation poses more potential hazard to pregnant women and her fetus during early pregnancy. High radiation dose to mother can result in embryo death or leukemia can be induced during childhood[3]. Federal agencies, state and other regulatory agencies such as JCAH (Joint Commission on Accreditation of Hospitals) have strongly recommended establishing good quality assurances procedures to minimize unnecessary radiation exposures.

Rem: Radiation absorbed dose unit (Rad x RBE value). Relative Biological Effect (RBE) is a factor of different types of radiation.

Method and Equipment

Experimental data was obtained to measure skin exposure using thermoluminescent dosimeters. Teflon-mixed lithium fluoride chips (TLD-100, 1/8" x 0.035") were placed directly on the skin of the patients during diagnostic examination. The exposed TLD's were read by a Harsha Model 2000-B automatic integrating picometer. TLD's were calibrated with low energy x-rays and annealed before using for dosimetry. TLD's measured values for different types of examinations were compared with computer calculated skin exposure values from Dupont radiographic techniques guide. The results are shown in table 1 and graphically in figures 1 and 2. These results vary from 3 to 10%. This variation is due to calibration and annealing techniques of TLD's. Estimated absorbed doses for various critical organs are computed from the skin exposure data[5] and reported in table 2. Absorbed doses to critical organs in Nuclear Medicine are reported in table 3. These doses are computed from the technical data provided by the manufacturers of radiopharmaceuticals and reference books[6],[7].

Discussion

The reported radiation doses in clinical studies are within safe limits. The repeats of x-ray procedures and misadministration of radiopharmaceutical will increase the risk of radiation damage. In Nuclear Medicine, care must be taken to avoid I^{131} thyroid scan or chest scan to a pregnant woman during her early pregnancy. As the deposition of I^{131} radioiodine in the fetus thyroid can give high radiation dose and can cause a high risk of leukemia to newborn children during childhood. There

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Table 1. RADIATION EXPOSURE IN DIAGNOSTIC X-RAY EXAMINATIONS

Type of Examination	*Thickness (cm)*	*TLD's Measurement (mR)*	*Calculated (DuPont) Technique (mR)*
Chest PA	*20-22*	*36*	*30*
Lateral	*32-35*	*47*	*45*
Abdomen	*18-19*	*315*	*300*
Skull AP	*19-20*	*355*	*300*
Lateral	*14-15*	*125*	*120*
Ribs, Barium Swallow	*20-23*	*425*	*400*
Shoulder	*12-14*	*89*	*80*
Cervical Spine AP	*8-9*	*45*	*40*
Lateral	*6-7*	*110*	*100*
Lumbar Spine	*18-19*	*420*	*400*
Hip AP	*18-19*	*260*	*250*
Pelvis	*20-21*	*535*	*515*
Femur	*12-14*	*172*	*160*

**Tef in-mixed lithium fluoride chips*

Table 2. ESTIMATED RADIATION DOSES TO CRITICAL ORGANS IN X-RAY EXAMINATIONS

Type of Study	Skin Dose (mR)	Testes (mRad)	Ovaries (mRad)	Thyroid (mRad)	Active Bone Marrow (mRad)	Embryo(m Rad)
Chest	AP* 30 Lat:* 45	0 0	0 0	1.0 4.5	2.8 1.4	0.03 0.02
Skull	AP: 300 Lat: 120	0	0	152 28	5 6	0 0
Abdominal	300	10.4	132	0.01	21.5	172
Lumbar Spine	400	1.8	94	0.16	16	125
Ribs, Barium Swallow	400	0	0.08	36	4.8	0.07
Pelvis	515	39	131	0	16	141
Cervical Spine	AP: 40 Lat: 100	0	0	133 17	1.8 8.3	0
Hip	AP: 250	185	29	0	4.0	60
Shoulder	80	0	0	0	1.7	0
Femur	160	48	1.0	9	1.2	1.2

*AP - antero-posterior
**Lat - lateral

is no significant damage to the fetus from 1 to 5 rads of radiation dose. It has been reported that the increased risk of leukemia from 2 rads is 1 in 2000. The abortion is considered up to 10 rad. However, this decision is based on the expectant mother's ethnic and religious background[4] and advice of the physician.

In diagnostic x-ray, the radiaition can be reduced by implementing effective quality control procedures, introducing faster film system, improved collimation and image intensifying devices. Radiation doses can be further reduced with additional filtration of Yttrium. It has been reported that (3mm Al $\pm$ 0.1 mm Yttrium) filters can reduce radiation exposure from 50% to 70% without affecting the quality of image[10]. With the implementation of good quality control procedures for equipment and diagnostic procedures, strict adherence to the existing regulations will reduce the risk of radiation hazard and will increase the patient care.

Table 3. RADIATION DOSES TO CRITICAL ORGANS IN NUCLEAR MEDICINE

TYPE OF STUDY	ABSORBED RADIATION DOSE IN RAD							
	Thyroid	Ovaries	Testes	Bone Marrow	Whole Body	Liver	Lung	Other
Brain Scan 99m Tc Sodium pertecnitate (Rad/30 mci)	3.9	0.66	0.3	0.6	0.42			Brain: 0.42 stomach wall: 7.5
Bone Scan HDP-99m Tc (Rad/20 mci)		0.34	0.22	0.56	0.13			Bone: 0.7 Kidney: 0.8
Hepatobiliary Disofenin 99mTc (Rad/mci)		0.08	0.01	0.3	0.016			Large Intestines:0.4 Gall bladder:0.2
Liver Scan 99m Tc (S.C.) (Rad/4 mci)		0.05	0.01	0.22	0.15	2.7		Spleen: 1.7
Lung Scan MAA - 99m Tc (Rad/4 mci)		0.03	0.03		0.06	0.07	0.88	Kidney:0.05
Gallium-67 (Rad/5 mci)		1.5	1.25	9.0	1.3	3.15		Kidney:2.7 Stomach:1.5
Thyroid Scan 131I(Rad/100 uci)	120	0.042	0.042		0.061			

Thyroid scan with 5 mci of 99mTc per pertecnitate The dose © 0.66 Rad/scan

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