EVALUATION OF DIAGNOSTIC X-RAY CONTRIBUTION TO THE ANNUAL GENETICALLY SIGNIFICANT DOSE EQUIVALENT OF TAIWAN URBAN POPULATION

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Abstract

Thermoluminescent dosimeters (LiF-teflon discs) were distributed to clinics and hospitals using X-rays for diagnostic purposes in Hsinchu which is a medium size city of Taiwan with a total population of 213,735. The dosimeters were placed inside a small pocket stitched on a piece of cloth. Before irradiation the patient was covered with this cloth of which the location of the pocket was adjusted to be against the gonadal region of patient's body.

The detailed record of the irradiation conditions and the status of patients were provided by the clinics and hospitals concerned. Dosimeters were replaced and read in a one-month interval. Based on the formula given by the United Nations Scientific Committee of the Effects of Atomic Radiation the annual genetically significant dose equivalent was calculated with proper corrections for gonad dose of both sexes.

Since one half of Taiwan population is living in the cities nowadays, and surveys of medical radiation sources in Taiwan have been carried out twice since 1970, the annual genetically significant dose equivalent calculated for Hsinchu is extended to Taiwan urban population. It shows that the annual genetically significant dose equivalent of Taiwan urban population was in the range of 3 to 4 mrem in 1972.

Introduction

The hazard of radiation exposure of most concern has shifted from relatively high doses received by a few people to low doses received by a large segment of the population. The diagnostic X-rays belong as a contributor to the latter category. This paper is concerned with doses from diagnostic X-ray received by gonads of the Hsinchu population during an eight-month investigation period as recorded by thermoluminescent dosimeters.

Hsinchu is a medium size city of Taiwan with a total population of 213,753 (1972 census). Of all inhabitants 113,921 are male and 99,814 are female. The medical radiation sources surveyed in 1970 and again in 1972 show that there are 15 diagnostic X-ray units in operation, i.e., 70 X-ray units per 10^6 population.[1] Of the 15 hospitals and clinics equipped with diagnostic X-ray units, only 5 major hospitals or clinics have frequent use of the equipment. The other 10 hospitals and clinics have a few exposures taken every year. Based on this information, the

major hospitals and clinics were chosen for this investigation and the characteristics of their X-ray units are shown in Table 1.

Table 1. The Manufacturers, Applied Voltages, and Beam Currents of X-ray Units in Hsinchu Major Hospitals and Clinics.

Hospital No.	Manufacturer	Filter (mm Al)	Radiography kVp	mA	sec	Fluorography kVp	mA	sec
1	Aroma	2.0	95	300	0.1	95	4	60
2	Shimadzu	2.0	60	300	0.5	60	2.5	180
3	Toshiba	2.5	100	500	0.05	70	3	60
4	Toshiba	2.5	70	200	0.25	70	2.5	120
5	Picker	2.5	75	100	0.05	70	3	60

Procedures

The 13 mm diam. x 0.4 mm thick discs of ^{7}LiF-Teflon of Teledyne Isotopes were used because of the consideration of the maximum sensitivity. The minimum dose defined as three times the standard deviation of the background is 15 mrad. The tissue-equivalence of LiF-Teflon dosimeters enables meaningful estimates of dose in X-ray radiation from a single measurement of a dosimeter at the monitoring site. The response is independent of photon energy to within $\pm$30% down to 20 keV. In addition the LiF-Teflon discs are unaffected by extremes of humidity and environmental temperatures which do exist in Taiwan. Readout LiF-Teflon discs was performed on Teledyne Isotopes Model 7100 TLD instrument. Nitrogen was supplied to suppress the spurious thermoluminescence during readout procedure. The standard deviation was about 3.6%.

Two LiF-Teflon discs each were placed inside a small pocket stitched on a piece of cloth for radiography and fluorography, respectively. Before irradiation the patient was covered with this cloth of which the location of the pocket was adjusted to be against his-her gonadal region. The detailed record of the irradiation conditions and the status of patients were replaced and read in a one-month interval. Table 2 present the results of an eight-month investigation period in 1972.

Table 2. The Average Exposure per Capita due to Diagnostic X-rays Monitored with LiF-Teflon Discs at the Gonads.

Month	Hospital No.	mR/man-exposure		Number of Patients							
				Radiography				Fluorography			
				Age			Total	Age			Total
		Radio-graphy	Fluoro-graphy	<18	18-45	>45		<18	18-45	>45	
1	1	28	243	11	141	31	183	1	2	3	6
	2	15	303	15	28	13	56	1	4	4	9
	3	16		10	17	42	69				
	4	62	273	3	28	13	44		7	5	12
	5	25	242	5	46	5	56	5	18	14	37
2	1	32	218	32	261	42	335	2	2	2	6
	2	78	233	12	36	27	75		7	9	16
	3	11		2	35	63	100				
	4	7	453	1	103	24	128		13	6	19
	5	42	363	4	18	6	28	5	63	5	73
3-4	1	23	145	65	476	67	608		3	4	7
	2	48	414	17	90	50	157	1	16	15	32
	3	38			24	81	105				
	4	17	487	4	98	49	151		34	10	44
	5	37	212	10	77	22	109	44	229	56	329
5-6	1	30	342	83	1101	52	1236	1	2	6	9
	2	46	320	25	99	75	199	1	19	7	27
	3	18			5	22	27				
	4	22	256	1	207	82	290	1	54	18	73
	5	38	285	9	68	23	100	45	210	61	316
7-8	1	25	246	90	1320	48	1458	1	3	9	13
	2	40	381	30	110	86	226	1	20	8	29
	3	32		2	30	88	110				
	4	36	298	4	102	67	173		51	11	62
	5	40	240	13	86	31	130	46	253	61	360
Average or Total		32	298	448	4606	1109	6153	155	1010	314	1479

The annual genetically significant dose equivalent to the population is a measure of the genetic significance of the yearly dose equivalent received by the population's reproductive organs (gonads). To calculate this dose equivalent, one should consider the gonad dose and the future number of children expected by each member of the population as listed in Table 3.

Table 3. Age-Group and Average Expected Children Census

Age	Population (%)	Average Expected Children
0-18 years		
(M)	19.9	4.00
(F)	18.4	4.00
18-45 years		
(M)	23.6	2.30
(F)	21.7	2.30
>45 years		
(M)	9.8	0.015
(F)	6.6	0.015

Table 3 was taken from population and birth rates census data released by the National Health Administration of Republic of China.

The genetically significant dose equivalent described here has the same meaning as that given in the report of the UNSCEAR.[2] The genetically significant dose equivalent can be calculated with the following formula:

$$D = \frac{\sum_j \sum_k \left(N_{jk}^{(F)} W_{jk}^{(F)} d_{jk}^{(F)} + N_{jk}^{(M)} W_{jk}^{(M)} d_{jk}^{(M)}\right)}{\sum_k \left(N_k^{(F)} W_k^{(F)} + N_k^{(M)} W_k^{(M)}\right)} \qquad (1)$$

where

D = annual genetically significant dose.
N_{jk} = number of individuals of age-class k, subjected to class j exposure, i.e., either radiographic or fluorographic X exposure.
N_k = total number of individuals of age-class k.
W_{jk} = future number of children expected by an exposed individual of age-class k subsequent to a class j exposure.
W_k = future number of children expected by an average individual of age-class k.
d_{jk} = gonad dose per class j exposure of an individual of age-class k.
(F) = female.
(M) = male.

Since the radiation levels and exposure frequency from diagnostic X-rays are quite low, the number of expected children will be the same for individuals after irradiation as it was before. Therefore, for the purposes of these calculations W_{jk} will be assumed to be the same as W_k.

For calculation of male and female gonadal dose, the correction factors K_m and K_f can be used, where

K_m = Depth dose at male gonads/skin exposure,
K_f = Depth dose at female gonads/skin exposure.
The central axis depth dose factors used to calculate depth dose to gonads from air dose were K_m = 72% and K_f = 11%.[3]

During the investigation period, it was assumed that the number of exposures taken was equal to the number of patients being examined. According to the data provided by the hospitals and clinics, patients under age 18 were less than 10% of all patients concerned. Hence, it was assumed that the gonad dose was independent of age-class.

Results and Discussion

The gonad doses thus obtained were as follows:

1. Radiography
   $d^{(F)}$ = 3.52 mR
   $d^{(M)}$ = 23.04 mR
2. Fluorography
   $d^{(F)}$ = 37.78 mR
   $d^{(M)}$ = 214.56 mR

For practical purposes, in X-ray diagnosis, an exposure of 1 R can be regarded as delivering to soft tissue a dose of 1 rad or a dose equivalent of 1 rem.[4] The annual genetically significant dose equivalent in Hsinchu City due to diagnostic X-ray only was 3.83 mrem in 1972.

The major cities in Taiwan are Keelung, Taipei, Taichung, Tainan, and Kaohsiung with a total population of 5,034,267 of which 2,683,264 are male and 2,351,003 are female. The number of diagnostic X-ray units is known.[1] Based on the data surveyed at Hsinchu City, it can be estimated that the annual genetically significant dose equivalent due to diagnostic X-rays in major cities of Taiwan was 3.64 mrem in 1972 while that of U.S.A. was 5 mrem. Since one half of Taiwan population is living in the cities nowadays, it is concluded that the annual genetically significant dose equivalent due to diagnostic X-rays of the Taiwan urban population was in the range of 3 to 4 mrem in 1972.

References

1. WENG, P.S., CHENG, C.H., WEI, V.R., and LIU, K.Y., "Survey of Medical Radiation Sources in Taiwan," Health Physics, 23, 549-553 (1972).

2. Report of the United Nations Scientific Committee of the Effects of Atomic Radiation (1958, 1962).

3. BROYLES, M., NEELY, O., SLINKMAN, R., and THIERFELDER, C., "Evaluation of Television Contribution to Annual Genetically Significant Radiation Dose of the Population," Radiological Health Data and Reports, 7, 363-370 (1971).

4. "Protection of the Patient in X-ray Diagnosis," ICRP Publication 16, Pergamon Press, Oxford, England (1969).