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A survey of annual effective and genetically significant dose from conventional X-ray examinations in 10 counties in Khorasan province-Iran

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Background: A study has been conducted to assess two useful radiation protection indices, the annual per-capita effective dose equivalent (AED) and the genetically significant dose (GSD), from conventional diagnostic radiography in 10 counties with more than 1,886,000 inhabitants in Khorasan province in Iran. ***Materials and Methods:*** The health centre authorities of Khorasan province were asked to record data of their patients (sex, age, weight and height) who had undergone radiography during one month starting October 2002, with the radiography specifications (kVp, mAs, FSD, field size) and conditions of the X-ray machines (filtration, model and performance). Based on the gonad absorbed dose level, the radiography data were first divided into 5 groups. Then, the average gonad and effective dose of the radiography groups were estimated using ODS-60 software, and finally, GSD and AED of each county were calculated. ***Results:*** Average number of radiography per thousand inhabitant was 34.5 in this study, which varied from 9.4 (Kashmar) to 109.4 (Ferdos). Number of X-ray units per 1000 population was 0.008. The GSD and AED of inhabitants in 10 counties in Khorasan province is 0.012 and 0.014 mGy/y/person respectively. ***Conclusion:*** The GSD and AED of 10 counties in Khorasan province were much lower than those in most of other countries, which would have been due to lower number of X-ray units and examinations per 1000 inhabitants. Although this would reduce the risk of radiation absorbed dose from medical diagnostic, but it also showed need to improve and expand the health care facility and services in those cities. **Iran. J. Radiat. Res., 2007; 5 (3): 113-118**

Keywords: *Annual effective dose, genetically significant dose, conventional diagnostic radiography.*

INTRODUCTION

It is a long time that X-ray units are used for conventional radiography in hospitals and health centers throughout all cities in khorasan province, no assay has been done about their performance (number of X-ray and frequency of examinations), and the radiation doses to populations. Therefore, a study has been conducted to assess the radiation protection indices of the population arising from conventional diagnostic radiography in the Khorasan province in Iran. The useful selected indices were decided to be the annual per capita effective dose equivalent (AED) and the genetically significant dose (GSD), which were also measured and assessed in many other countries [1-4].

As the medical exposure are not distributed uniformly, the NRPB provided the annual per capita effective dose equivalent as a better indication of all over trends in individual dose (due to changes in radiology practice) than the annual collective dose [5].

The genetically significant dose was also an estimated dose to the population's gene pool. It is an indication of the genetic load on the population that could affect genetic properties in the offspring. It is related to age, number of expected children, gender, and type of radiographic examinations. The annual genetically significant dose to the population was the average of the gonad dose received by individuals, each weighted for the expected number of children to be conceived subsequent to the exposure [4]. The genetically significant dose was initially defined by UNSCEAR, as a useful index to compare the radiation safety practices in

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various countries, as well as in the case of follow-up studies. It also estimated the risk of radiation dose from medical procedures to the population. Based on this definition, the National Radiation Protection Board (NRPB) introduced a formula which contained the frequency of medical examination and estimation the gonad dose for different types of examination together with the data of population and child expectancy in a defined district [4].

In the present study it has been aimed to evaluate the performance of X-ray units and frequency of examinations and radiation doses to population of Khorasan province. Therefore, gonad and effective doses of the patients attending to hospitals for different X-ray examinations were first estimated, using ODS-60 software, then the radiation protection safety indices were assessed in the population of 10 cities of Khorasan province, with more than 1,886,000 inhabitants.

MATERIALS AND METHODS

A data collection form was designed and sent to the health center authority of 17 cities in Khorasan province to formally ask the hospitals and health centers to record their patients' and radiological examination data, and send them to the researchers at the end of each month, stating from October 2002. Ten counties cooperate with the study for 1-3 months period. The data provided was to include sex, age, weight and height of the patients together with the Kvp, mAs, FSD, field size and type of medical examinations. The condition and model of X-ray machines with the amount of filtration were also recorded. The population data of each city, such as the populations of male and female, number of female aged 15 to 49, and general fertility rate was obtained from health vice-president of Mashhad University of Medical Science. Based on the received data from 13 X-ray units in 10 cities, the number and distribution of radiography per year were derived, and shown in table 1 with the population statistic data for each city.

The GSD and AED can be estimated using the flowing formula [4, 5]:

$$AED = \frac{\sum_l \sum_k N_{k.l} H_{k.l}}{\sum_k N_k} \quad , \quad GSD = \frac{\sum_l \sum_k N_{kl} P_{kl} \overline{D}_{kl}}{\sum_k N_k P_k}$$

Where N_{kl}, P_{kl}, $\overline{D}_{kl}$ and $H_{k.l}$ are respectively the number of patients, child expectancy of an individual, mean gonad and effective dose of patients, in the kth age-sex-county group, who underwent an examination of type l. P_k and N_k is child expectancy and the population of kth age-sex group of each county at the year defined.

To estimate GSD and AED, the collected row data were first controlled by a radiologist and the odds or missing fields were corrected, based on similar radiography at the same county. The corrected row data were then got into Excels worksheets' data. Using filtration facilities, the data were categorized into 5 groups which were assumed to be almost similar in gonad absorbed dose. The

Table 1. Number of radiography per year and population data of 10 cities in Khorasan province.

County	No. of radiography /year		Population		No. of female aged 15-49	General fertility
	Male	Female	Male	Female		
Bardaskan	3114	2349	34980	34127	17234	51.6
Bojnord	8101	4757	163799	157499	79537	79.4
Chenaran	1897	1373	58036	56898	28733	51.3
Dargaz	2811	1513	44721	43844	22141	62/0
Fariman	685	337	43685	43039	21735	80/1
Ferdos	5791	4368	47228	45631	23043	60/4
Ghochan	4340	2893	135122	129925	65612	59/5
Kashmar	996	920	103606	100102	50551	57/9
Khaf	772	907	53375	52328	26426	96/9
Torbat jam	3277	3847	124591	120962	61086	87/3

radiography groups were: head and neck, upper and lower extremities, chest, abdomen, and pelvic and lumbar spine. Distribution of examinations in terms of patients who were aged less than 15, 15-49, both male and female in different radiography groups are shown in table 2.

Averages of different fields of the collected data in terms of examination groups, which were almost the same for all cities, are shown in table 3. As no measurements were made for air kerma at the patients' entrance skin, it was calculated using the empiric formula suggested by Bahryni *et al.* 1999, which was

Table 2. Distributions of examinations in 10 cities in Khorasan province.

County	Radiography	Head & Neck		Extrimities		Chest		KUB, IVP, VCUG		Lumbar, Pelvic	
		F	M	F	M	F	M	F	M	F	M
Bardaskan	% all patients	6.7	7.3	17.1	28.5	11.8	14.5	2.0	1.8	5.6	5.6
	% <15	1.3	0.9	2.7	5.1	4.2	3.8	0.4	0.4	0.7	0.0
	%15-49 year	4.9	4.9	11.1	18.9	3.1	6.2	0.7	1.1	3.6	0.7
Bojnord	%all patients	4.4	8.2	10.6	27.2	12.2	13.1	3.5	9.7	6.0	5.1
	% <15	0.4	2.7	1.3	3.5	3.5	3.8	0.0	2.7	0.2	0.2
	%15-49 year	3.8	4.4	7.1	22.3	4.4	6.4	0.4	4.0	4.4	2.9
Chenaran	% all patients	6.8	9.0	13.1	28.1	16.6	14.8	2.1	3.2	3.0	3.3
	% <15	1.7	1.8	2.3	5.6	2.0	1.2	0.2	0.0	0.6	0.5
	%15-49 year	4.4	6.5	7.1	19.6	7.2	6.8	1.7	2.6	1.7	2.7
Dargaz	% all patients	3.9	7.5	17.2	37.0	9.7	10.4	1.3	4.9	3.2	4.9
	% <15	0.6	2.6	2.9	9.7	1.0	1.0	0.0	0.0	0.0	0.6
	%15-49 year	2.3	4.5	9.7	21.4	3.9	4.2	1.3	3.6	2.6	1.6
Fariman	% all patients	4.8	11.9	23.8	40.5	2.4	9.5	2.4	2.4	0.0	2.4
	% <15	0.0	7.1	9.5	16.7	0.0	0.0	0.0	0.0	0.0	2.4
	%15-49 year	4.8	4.8	11.9	21.4	0.0	7.1	0.0	2.4	0.0	0.0
Ferdos	% all patients	8.0	12.0	16.0	21.6	8.0	12.8	5.6	3.2	5.6	7.2
	% <15	1.6	4.0	6.4	4.0	0.0	0.8	0.0	0.0	0.0	2.4
	%15-49 year	6.4	7.2	8.8	16.8	6.4	4.8	0.8	3.2	4.0	3.2
Ghochan	% all patients	5.8	9.3	9.7	25.0	15.1	15.4	3.4	5.6	5.6	5.1
	% <15	0.5	3.9	1.4	5.3	2.2	2.4	0.5	0.7	0.0	0.7
	%15-49 year	3.9	4.8	4.8	15.4	3.7	5.8	2.2	3.9	3.4	2.2
Kashmar	% all patients	4.8	7.1	26.2	28.6	9.5	7.1	2.4	2.4	4.8	7.1
	% <15	2.4	0.0	2.4	7.1	0.0	2.4	0.0	0.0	0.0	0.0
	%15-49 year	0.0	2.4	19.0	19.0	2.4	2.4	0.0	0.0	2.4	2.4
Khaf	% all patients	6.5	10.9	13.0	15.2	13.0	4.3	17.4	8.7	4.3	6.5
	% <15	4.3	2.2	6.5	4.3	2.2	2.2	0.0	0.0	0.0	6.5
	%15-49 year	2.2	8.7	6.5	10.9	8.7	2.2	17.4	8.7	4.3	0.0
Torbat jam	% all patients	9.1	10.4	27.1	20.5	7.6	7.2	3.2	1.7	7.4	5.7
	% <15	0.4	1.3	2.7	0.9	2.5	2.8	0.2	0.0	0.2	0.2
	%15-49 year	7.0	6.6	17.8	15.0	3.6	3.2	1.7	1.1	4.7	3.2

based on kVp, mAs, field size and filtration of the radiography [6].

ODS-60 software estimated the organ and effective dose of any radiography, using data fields shown in table 3 [7, 8]. In this study to estimate gonad and effective dose of patients in any examination group, sex and county, average data of that county used. The ODS represented organ doses by mGy, and it was of no value in head and neck, as well as chest radiography. It also could not calculate the effective and gonad dose in extremities. Therefore, to evaluate those values, the method suggested by Hajizadeh *et al.*, was used [9]. In the method the organ and effective doses have been estimated bases on the amount of shielding, distances from center of examination field, and plus the radiography conditions.

RESULTS

Based on the average data of each city, the effective and gonad doses of the patients in different examination groups and sex were estimated by ODS-60, and shown in table 4.

As there has not been sufficient information about child expectancy of populations, only three age groups (<15, 15-49 and >49 years old) were assumed. It was also assumed that: 1) organ and effective dose of table 4 to be applicable for all ages, 2) maximum child expectancy (MCE) derived from general fertility rate was true for those aged <15, and it reduced to zero for female at 49 and men at the end of their lives. MCE of female was derived from general fertility rate (GFR) by 34×GFR/1000, and male by using their relative population factor. Based on these assumption and the data presented in tables 1, 2 and 4, values for GSD and AED were calculated, using formulas introducing in material and method, and shown in table 5.

DISCUSSION

Average number of radiography per 1000 inhabitant was 34.5 in this study, which varied from 9.4 (Kashmar) to 109.4 (Ferdos). The value was lower than that (362) reported by Bozarjimehri *et al.* for Yazd city, and few other near by cities [11], and much lower than that showed in the report of Hering for West Germany (1500), France (800), Japan (800), USA (700), England (400), Italy (350) [3]. It is 4 of that in health care level-II (HCL-II)

Table 3. Averages of different fields of the collected row data vs. examination groups.

Examination groups	Sex	kVp	mAs	FSD	Field size		Kair	Weight	Height	Age
				Cm	cm	cm	mGy	Kg	cm	Year
Head & neck	F	70.3	41.0	96.2	21.2	27.3	2.6	56	155	29*
	M	65.3	34.2	93.0	20.4	26.5	1.9	54	155	28*
Extremities	F	53.7	10.0	93.9	18.5	25.8	0.3	54	149	32
	M	54.9	10.3	94.9	20.2	30.2	0.4	57	155	27*
Chest	F	75.7	23.6	151.6	32.1	34.6	1.0	54	149	41
	M	74.5	21.2	143.9	30.4	33.0	1.0	54	149	36
Abdomen (KUB, IVP, VCUG)	F	80.0	67.2	95.4	33.8	41.6	7.0	59	155	44
	M	77.9	57.6	95.7	33.2	41.8	5.6	64	165	39
Limbo Sacral, Pelvic	F	71.0	56.6	86.3	25.9	34.2	5.5	54	142	37
	M	76.8	54.1	98.4	26.3	36.4	5.2	54	149	35

Table 4. Effective (μSv) and gonad (μGy) dose of different radiography groups, both male and female, in each city.

County	Sex	Head & Neck		Extremities		Chest		Abdomen		Lumbar, Pelvic	
		Effective	Gonad	Effective	Gonad	Effective	Gonad	Effective	Gonad	Effective	Gonad
Bardaskan	F	50	9	2	2	150	5	880	1040	910	1450
	M	50	11	2	2	140	4	440	50	550	70
Bojnord	F	160	19	2	3	150	4	2360	2760	1860	2690
	M	80	11	2	2	180	5	1450	610	1440	260
Chenaran	F	60	10	2	3	340	15	2250	2590	1570	2270
	M	50	8	3	3	310	15	1510	200	1510	460
Dargaz	F	120	15	3	4	190	7	3590	4200	2910	4380
	M	100	13	3	4	180	7	1780	180	1170	180
Fariman	F	60	9	1	2	290	8	2360	2930	-	-
	M	10	5	2	3	210	7	1470	1900	-	-
Ferdos	F	80	39	11	13	260	15	4120	5060	1110	1870
	M	60	36	9	11	130	12	1610	150	670	40
Ghochan	F	60	8	2	3	100	8	840	1050	690	1130
	M	50	9	2	2	90	8	460	100	320	50
Kashmar	F	190	19	4	5	270	5	10690	13570	2180	3170
	M	30	6	5	6	200	5	5070	820	2680	200
Khaf	F	230	20	1	1	780	19	4010	4780	6010	8580
	M	180	21	3	3	650	14	2080	150	2340	4160
Torbat jam	F	130	19	4	5	540	9	3130	3580	2110	3460
	M	100	18	5	6	620	9	2580	260	1060	30

Table 5. GSD and AED of 10 cities in Khorasan province.

County	AED	GSD
	uSv/y/per	uGy/y/per
Bardaskan	12.05	8.79
Bojnord	18.62	13.55
Chenaran	8.67	4.36
Dargaz	16.39	10.79
Fariman	1.45	1.40
Ferdos	48.94	45.63
Ghochan	3.17	2.45
Kashmar	6.81	4.90
Khaf	23.15	23.91
Torbat jam	13.68	11.34
Total	13.79	11.69

countries (140) [12]. The frequency of X-ray units per 1000 populations has been 0.008 which was 10 of that in HCL-II countries (0.086) [12]. So, it proved that despite of lower examination per capita, the load on X-ray units were almost 2.5 times more, in comparison with the mentioned. This could have been due to the followings:

- Lack of complete coverage of healthcare and diagnostic facilities and services in the cities under study.
- Refer of some patients to the nearest larger cities for their medical services.

The AED per capita derived in this study was 0.014 mSv/y/person. The amount was much lower than what reported for North East of Italy (0.848) [2], USA (0.396), and Riyadh (0.28) [10]. Bouzarjomehri reported this value for Yazd province (0.036) and compared that with developed countries such as UK (0.2), Switzerland (0.75), Netherlands (0.27), and some HCL-II countries such as Malaysia (0.04) and India (0.02) [11].

The GSD of inhabitants in 10 cities of Khorasan province was 0.012 mGy/y/person. This was lower than that reported by Hering for South Africa (0.095) and much lower than the countries such as Australia (1.59), Switzerland (0.72), Japan (0.39), North Italy (0.253), Denmark (0.22), USA (0.20), UK (0.14), Newzeland (0.12) [3] and also less than Riyadh area in Saudi Arabia (0.109) [10]. It was almost nearly the same value as reported for India (0.011) in 1974 [1].

Despite more radiography in men, the contribution of female to the GSD was much larger than that of males; this could be attributed to the fact that the doses to female gonad from examination of abdomen, pelvis, and lumber spine were much larger than those of the male gonads [3].

CONCLUSION

Although performing radiography with low kVp-high mAs mode, the GSD and AED of 10 cities in Khorasan province were much lower than those in most of other countries, which would have been due to lower number of X-ray units and their examination per 1000 inhabitants. Although, this would reduce the risk of radiation absorbed dose from medical diagnostic, it showed that there was a serious need to improve and expand the health care facility and services in those cities. Also, it was necessary to complete this study by updating the data and accounting the referring patients of those cities to larger neighboring cities, or adding the data for Mashhad, Sabzevar and Birjand to them to complete the GSD and AED of the whole Khorasan province.

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