Radiation exposure of the Yazd population from medical conventional X-ray examinations

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Background: Radiation dose knowledge through X-ray examinations and their distribution in Iran provides useful guidance on patient dose reduction. The results of the entrance skin dose (ESD_s) of five common radiographies in all radiology centers in Yazd province were reported in our previous study (2003). In the present study we have evaluated the collective effective dose of conventional X-ray examinations, as well as the annual per caput of Yazd population. ***Materials and Methods:*** The annual frequencies of 18 different types of conventional radiology examinations during April 2005 to March 2006 were recorded from all 35 radiology centers in Yazd province. The exposure conditions consisted of kVp, mAs, and Focus surface distance (FSD) of the examinations for the mode of exposure in each X-ray unit. 620 ESD were measured by diode dosimeter in 35 hospitals and clinics. The real exposure kVp for each radiology unit was measured by a Molt-O-Meter. The conversion coefficient (effective dose - ESD ratio) for each radiology examination was determined by using SR262 tables. Finally, the patients' effective dose was calculated by multiplying the conversion factor to the ESD. ***Results:*** The patients' annual collective effective dose due to the conventional radiology examinations was 31.159 man-Sv (0.03 mSv per inhabitant). The frequency of examinations was 311813 i.e. 0.36 examinations per head of the population for one year. ***Conclusion:*** According to our findings, the effective per caput dose seems to be optimally relative to HCL-II countries, which may be due to low mean effective dose that could obscure high examination frequency. The number of radiology conventional examinations and frequency of radiologist per1000 population of Yazd was more and lower than HCL-II countries respectively. Thus the justification of radiography requests in this province must be revised. **Iran. J. Radiat. Res., 2007; 4 (4): 195-200**

Keywords: *ESD, effective dose, collective dose, medical conventional X-ray examination.*

INTRODUCTION

The effective dose is a dosimetry parameter which takes into account the dose received by all irradiated radiosensitive organs, and may be taken as a measure of the stochastic risk [(1)].

This dose descriptor is being increasingly used to quantify the amount of radiation received by patient undergoing diagnostic X-ray examinations [(2-4)]. Medical exposures are not distributed uniformly around the population, so the annual per caput dose provides a better indication of overall trends in individual dose, as radiology practice changes, than the annual collective dose [(2)]. According to the National Radiation Protection Bored (NRPB) report, contribution from patients undergoing X-ray examinations are nearly 90% of the total per caput effective dose from all artificial sources in the UK, with diagnostic nuclear medicine procedures contributing a further than 8% (excluding radiotherapy) [(5)]. All occupational and public exposures arising from medical and other uses of ionizing radiation amount to less than 3% of the total [(5)]. Although a vital feature of medical exposure is the direct benefit they provide to the healthcare of the exposed individual, medical exposures should be justified on an individual basis by offsetting the very small radiation risks for patients. A large per caput dose will be justified if all the individual medical exposures are justified (and optimized) [(5)].

The patient dose is highly dependent on the medical diagnostic X-ray procedures, so the population dose and dose distribution may be altered by the development of medical diagnostic X-ray techniques. Therefore the per caput dose result of medical X-ray

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examinations must be surveyed periodically.

The population dose of medical X-ray examinations has been determined in many countries, for example the medical radiation usage for diagnostic radiology in Malaysia was reported in 1999, and compared with United Nations Scientific Committee (UNSC) report. According to this report the annual effective per caput dose of Malaysia population and collective dose were 0.05mSv, 1000 Sv-man respectively [8]. The annual effective dose per capita arising from diagnostic medical exposures was reported 0.59 mSv (1998) in Netherlands which showed an increase of 26% related to their previous study. They suggested that this increase was due to increase in CT examination frequencies [9]. With patient dose monitoring and audit procedures becoming widely practiced, practitioners are adopting more dose-efficient procedures, and per caput effective dose estimation is an indicator to justify X-ray examinations.

The collective and per caput dose arising from medical X-ray examinations have not been estimated in Yazd province yet. In our previous studies, the Entrance Skin Dose (ESDs) of common X-ray examinations in all radiology centers of Yazd province were surveyed [6, 7], and the methods for reducing patient dose were suggested to the radiographers. Fortunately, those quality control programs led to significant decrease in patient dose in those radiology centers [6]. In the present study, the conventional X-ray examination frequencies and the effective dose arising from each examination were determined in Yazd province for the first time.

MATERIALS AND METHODS

To estimate the annual per caput effective dose of the common radiology examinations, the annual frequency and the mean effective dose for each type of examination were determined. These examinations were obtained using 53 stationary radiology units in Yazd province for one year (from April-2005 to march-2006). These radiology units consisted of: 15 units Varian (Iran), 10 units Toshiba (Japan), 10 units General Electric (USA), 7 units Shimadzu (Japan), 5 units Parspad (Iran), 4 units Siemens (Japan), 4 units Medicore (Hungary) and 3 units from other companies. The radiographies had been achieved in Yazd province consisted of 18 different types, each with one, two or more than two views of projections (the experiment was carried out on in 22 centers in Yazd a 13 others in other cities). A questionnaire was sent to each radiology center to indicate the examination frequency and the mode of radiography exposure conditions (kVp, mAs, Focus Film Distance (FFD) and filter thickness) for 32 different radiography views.

Effective dose is a valuable parameter for comparing risk arising from different radiation sources but its precise determination is complex. National Radiological Protection Board (NRPB) has published in SR262 report of the conversion coefficients which is the ratio of effective dose to ESD. This report provides the tables containing the effective and organ doses for each radiography view according to any ESD values. The tables were calculated based on Monte Carlo simulation of exposure relevant to 68 common radiography views.

The ESD values for each 32 radiography views were measured by a diode dosimeter (UNFORS model 6001, Sweden) for all related radiology examination in all radiology centers in Yazd province. To use SR262 tables, we needed to have real kVp, so we used a Molt-O-Meter (UNFORS model-601, Sweden) to measure it from X-ray tube exposure. The NRPB-SR262 contained conversion coefficients, in which the effective or organ dose for 68 radiography views was calculated for one ESD. To use NRPB-SR262 tables, X-ray spectra (Tube voltage and total filtration) were required. The effective doses arising from each X-ray examination, except for extremities, were calculated by multiplying ESD by relevant conversion coefficient which was found in NRPB-SR262 tables. To calculate the effective dose related to extremity radiographies, the conversion coefficients reported by NRPB-W4 [7] report were used.

The dosimeter and Molt-O-Meter were calibrated by Iran secondary standard dosimeter laboratory (SSDL) and found to be capable of performing at the recommended level of precision and accuracy. To measure ESD the detector was placed on the table in the center of projection with the relevant field size, and focuses surface distance (FSD) of each projection. The ESDs values were measured Free-in-air; i.e., without phantom or backscatter. In the radiology centers selection of exposure factors (kVp, mAs and FSD), by each operator is different for the same projection, thus the mean of used values were considering. The annual patient frequency for each projection was considered as a weighting factor for collective effective dose (man-Sv). According to data reported by province management and designer organization, the population of Yazd province was 863270 in 2002.

RESULTS

During the period of a year (from April 2005 to March 2006), 311813 radiology examinations had been carried out Yazd province. Table 1 shows the annual frequency of each conventional X-ray examination

Table 1. Frequency of medical common X-ray examinations, mean effective dose arising from each radiology examination and collective dose.

Examinations Type	Number of Examinations	% frequency	Patient Effective Dose (PED) µSv	%PED	Collective (mSv-man)
Lower Extremity	87740	28.1	1.46±0.4	0.02	128.1
Upper Extremity	54502	17.5	1.02±0.3	0.019	55.6
Shoulder	11242	3.6	6.65±3.3	0.12	74.7
Chest PA	62844	20.1	45.3±25.2	0.85	2846.8
Chest Lat & PA	6127	1.96	125±78	2.3	765.8
Skull	19474	6.2	25.4±11.4	0.48	494.6
Thoracic Spine	4558	1.4	391.6±173	7.4	1785
Lumbar Spine	15538	4.9	665.5±297	12.5	10340.5
Pelvis	11699	3.78	416.8±122	7.9	4876
Lumbo-Sacral joint	4404	1.4	115±101	2.1	506.5
Cervical Spine	11312	3.6	48.8±14	0.9	552
Abdomen	12420	4	304±127	5.7	3775
Hip joint	4005	1.28	171±68	3.2	685
Stomach and Duodenum	788	0.25	426±274	8	335.5
Kidneys and Ureters	3297	1.0	882±479	16.6	2908
Oesophagus	689	0.22	212±72	4	146
Small Intestine	538	0.17	390±122	7.3	210
Barium Enema	636	0.2	1058±477	20	673
Conventional Radiology	311813	100	5286	100	31159

which included consist one, two or more than two different views and repetition of projections. The chest X-ray examinations after the extremity organ radiographies were the most abundant examinations among the others. The mean and the standard deviation of effective dose of Barium enema examinations were 1058 ± 477 µSv which had the most values among all radiology examinations. To determine annual collective dose for each X-ray examination in each radiology center, the annual frequency of each X-ray examination was multiplied by its effective dose. The mean effective dose for chest X-ray examinations wasn't very high, but its collective dose, due to their high frequencies was very high. The collective dose indicated in table 1 for each radiography projection was the sum of collective dose calculated from each radiology center related to that specific view.

In table 2 the frequency of 11 different X-ray examinations per 1000 population, per year, and their effective doses are compared with UK and Malaysia as HCL-I and HCL-II countries, respectively. The frequency of radiology units, radiologists and conventional X-ray examinations per 1000 population per year in Yazd, HCL-I and HCL-II countries are summarized in table 3.

Table 3. Number of radiologists, X-ray units and examinations per 1000 population of Yazd (April 2005 to March 2006) in compare with HCL-I and HCL-II countries [11].

Quantity	YAZD	Level II	Level I
Radiologist per 1000 population	0.016	0.041	0.11
X-ray units per 1000 population	0.09	0.086	0.35
X-ray examination per 1000 population	362*	140	863

* X-ray examination excluding CT and interventional examination

DISCUSSION

Although diagnostic medical exposures

Table 2. Comparison of examination frequencies and typical effective doses UK as HCL-I countries and Malaysia as HCL-II countries [7, 8].

Examinations Type	Number of examinations per 1000 population per year			Typical effective dose (mSv)		
	Yazd	Malaysia	UK	Yazd	Malaysia	UK
Chest	80	115	141	0.05±0.02	0.03	.02
Lumbar spine	18	-	19	0.66±0.3	1.8	1.3
Cervical spine	13	-	14	0.048±0.01	N	N
Pelvis/hips	18	8	31	0.4±0.1	1.0	0.7
Skull	22	10	28	0.02±0.01	0.04	0.04
Urography	3.8	0.6	4.6	0.9±0.4	2.4	2.4
Upper GI tract	0.9	1.5	4.9	0.4±0.2	6.0	2.6
Lower GI tract	08	1.5	6.1	1.06±0.5	6.0	7.2
Limbs and Joints	165	31	147	.001±.0004	0.04	N
Thoracic spine	5.3	13	5	0.4±0.1	-	0.7
Abdomen	14	7	21	0.3±0.1	1.0	0.7
Total	362	187.5	421	4.18	12.3	15.3
Effective per Caput Dose	0.03	0.05	0.2			

have been the major source of man-made radiation exposure of the population, their use is justified when clear clinical benefits for the patient are expected [10]. Studies assessing annual collective doses and associated radiation risk are important to support appropriate use of radiological investigations, and to fulfill national and international regulations as well as to inform radiation protection and public health authorities [10]. According to our findings, the annual frequency of conventional X-ray examinations in Yazd was 362 per 1,000 inhabitants, which was lower than the relevant value in the HCL-I countries (863), and more than the HCL-II countries (140). Although the frequency of X-ray units per 1000 population in Yazd province (0.09) was almost the same as the HCL-II countries, number of radiologists per 1000 population in this province was less than one third of HCL-II countries (0.016 Vs 0.041). The number of radiologist per 1000 X-ray examinations in Yazd was lower than relevant value in the HCL-II countries [11] (0.04 Vs 0.29). So it was implied that hospitals in Yazd should have 35 radiologists instead of 14, to match those of other countries. Increasing the number of radiologists will lead to increase accuracy of radiography reports. The data presented in table 1 indicate that the annual collective dose of the conventional X-ray examinations was 31159 Sv-man; therefore considering the total population 860,000 in Yazd province [16], the annual effective dose per caput will be 0.036 mSv. This value was lower than the developed countries such as UK (0.2 mSv), Switzerland (0.75mSv) and Netherlands (0.27), but it was similar to the HCL-II countries such as Malaysia (0.04mSv), and India (0.02mSv) [8, 12]. In the present study the effective dose was determined based on the measurement of individual ESDs which was lower than the typical effective dose recommended by European commission 2000 [12]. This reduction in ESD can be the result of radiology centers limitation (35) and the types of radiology examinations (18), as well as the developing of good quality control on radiology centers. According to the literature review, there was no published data about effective per caput dose measurement in other Iran provinces so we couldn't compare our results with provinces other in Iran and even most other HCL-II countries [11]. A traditional tool for dose restriction in diagnostic radiology is the "justification" of each individual X-ray examination [13]. The European referral criteria give a guide to the radiation caused by medical imaging and recommend investigations in various clinical settings. These recommendations should play an important role in the justification of radiological examination by avoiding unnecessary and unjustified examinations [12]. Base on ICRP estimate the radiation-induced cancer mortality at low dose to be 5% per Sv for the whole population [14], so the conventional X-ray examination of Yazd province may had induced 1.6 mortality cancers per year (during 2005-2006).

Although the effective per caput dose in Yazd province is almost the same as HCL-II countries, but it could be lower by decrease in frequency of unnecessary examinations. To decrease X-ray examination frequency in Yazd province it was suitable to make the referral guidelines available for all doctors and hospitals.

CONCLUSION

Although the use of ionizing radiation for diagnostic medical procedures is an accepted part of modern medicine, the importance of keeping the patient dose as low as possible was clearly marked by the European Directive 97/43/EURATOM [15]. There is also the potential for inappropriate use and unnecessary radiation dose so the request of radiography must be justified.

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