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

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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 0.05 mSv, 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

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coefficients reported by NRPB-W4 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.

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

**DISCUSSION**

Although diagnostic medical exposures
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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REFERENCES


