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Radiation Exposure of Patients Undergoing Common Diagnostic X-Ray Examinations in Some Major Hospitals in Visakhapatnam, India

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Abstract

Background: Everyone alive in this world is constantly being exposed to ionizing radiation and about 18% exposure is due to man-made source. Recent developments in medical imaging have led to rapid increases in a number of high dose x-ray examinations performed with significant consequences for individual patient doses and for collective dose to the population as a whole. It is therefore important in each country to make regular assessments of the magnitude of these large doses.

Objectives: To calculate collective dose of the population as a result of radiation dose from diagnostic x-rays, thereby to estimate the annual effective dose per patients which would be reduced by the use of rare earth intensifying screen.

Materials and Methods: Data on the number of diagnostic procedures using x-ray examination in year 2010 in one governmental and four private Hospitals by body site were collected in Visakhapatnam. Typical effective doses for those examinations making major contributions to collective was calculated according to the European Guidance on Estimating Population Doses from Medical X-rays .The annual collective effective doses from x-ray diagnostics were obtained by multiplication of the estimated effective doses per examination type with the corresponding annual frequency and summation over all types of examination. The results were then collected and entered into a database for analysis.

Results: A total of 46350 (1.2 exams/patient) medical examination were collected in five hospitals in year 2010. The total collective dose to all patients from diagnostic plain x-rays, IVU and Barium studies was 47.3 man.Sv, this result in an annual effective dose per patient of 1.23 mSv. Lumbar spine and Barium follow accounted 13.65 man.Sv (28.88%) and 13.08 man.Sv (27.67%) of the total annual collective dose which results in 15.5% and 2.8% of exposures respectively.

Conclusion: Although the use of ionizing radiation for diagnostic medical procedures is an acceptable part of modern medicine, there is also the potential for inappropriate use and unnecessary radiation dose to the patient, so the request of high dose procedures must be justified.

Keywords: Diagnostic X-ray examination; Radiation exposure; Effective dose; Collective dose; Per caput effective dose

Introduction

Diagnostic imaging using X-rays goes back to the time of Roentgen's discovery in 1896. Diagnostic procedures, particularly the widespread use of X-rays, continue to be the most common application of radiation in medicine [1,2]. Recent developments in medical imaging modalities particularly with respect to computed tomography (CT) have led to rapid increases in a number of high dose X-ray examinations performed with significant consequences for individual patient doses. Although the use of radiation technology has led to vast improvements in the diagnosis and treatment of diseases; there are adverse effects that depend on the type and the intensity of radiation involved while some risk is generally acceptable when clear clinical benefits for the patient are expected [3,4]. Justified examination and treatments contributes greatly to health as welfare, but side effects include a risk of cancer and other stochastic effects in proportion to the dose [5-8]. The effects of low level of exposure to ionizing radiation are of concern to a large number of people including workers receiving exposure on job [1,5].

Assessment and optimization of radiation doses received by patients are some of the most important tasks for radiation protection of patients in diagnostic radiology. The doses received by the patients due to diagnostic radiations are extremely variable, depending on the type of exposures. To evaluate the risk to the population, United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [9] uses the term 'collective dose' which is defined as the product of the number of exposed individuals and their average effective dose. The collective dose can be used as a measure of the health detriment associated with the discharge practices considered and is one of several important quantities to be taken into account in assessing them [10]. Studies assessing annual collective doses 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.

Approximately 400 million diagnostic medical examinations and 150 million dental X-ray examinations are performed annually in the United States [1]. On average, each person receives at least two examinations per year. In the United States the annual individual and collective effective doses from diagnostic medical X-rays have

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been estimated as 0.5 mSv and 1,30,000 man.Sv [1] respectively. The population dose of medical X-ray examinations has been determined in many countries, for example: the medical radiation usage for diagnostic radiology in European countries was reported in 2008 [11,12]. According to this report, compared to other industrialized countries, Luxembourg has the upper range of annual effective per caput dose (1.83 mSv) while the annual effective dose per caput of Uk (0.38 mSv) is the lowest. In Germany, a decreasing trend in the overall frequency of X-ray examination was observed during the period 1996 to 2003 [11]. On the other hand, the mean effective dose per caput shows an increase from about 1.6 mSv in 1996 to about 1.7 mSv in 2003 [11]. This raise is mainly attributed to the increased application of computed tomography (CT). In contrast to CT exams the number of conventional X-ray examination deceases. In Netherlands, the annual effective dose per caput arising from diagnostic medical exposures was reported 0.53 mSv (1998) which showed a decrease to 0.45 mSv in 2002. They suggested Computed Tomography contributes the largest part to this number, 0.19 mSv [9]. In the study done in 1994, in Ukraine, collective dose to the patients due to X-ray procedures was 26,250 man.Sv and the mean dose including radionuclide is 0.5 mSv/caput. According to this study the levels of population exposure due to X-ray examination in Ukraine have decreased about twice during the past ten years. They found the cause for this reduction is reducing the number of examination and reduction on the number of the main dose forming fluoroscopy methods [13]. The decrease in the radiation to the patients has a great significance. The aim is not only to reduce the radiation exposure of individuals but also to have procedures carried out with maximum efficiency so that there can be continuing increase in medical benefits accompanied by a minimum radiation.

The patient dose is dependent on several operational parameters including peak kilo voltage (KVp), mili-Amper-second (mAs), body orientation (PA, AP etc.), grid, intensifying screens etc. Intensifying screens in general consists of a thin layer of tiny phosphor crystal mixed with a suitable binder and coated in a smooth layer on a plastic support or card board. The basic principle in the action of intensifying screen is utilization of a phosphor that converts energy carried by an x-ray photon into visible light. The speed at which intensifying screens can convert X-ray energy to radiation depends on physical properties (i.e. size and number of phosphors) and type of phosphor which is critical because of the ability to absorb X-ray energy. The conventional intensifying screens (calcium tungestate screens) have low absorption coefficient and conversion efficiency as compared to a newly developed rare earth screens [14-16].

The purpose of these screens is to reduce radiation exposure required to produce a diagnostic radiograph. This results in the usage of lower mAs (milli-Ampere-second) setting which is advantageous because of the ability to utilize shorter exposure times. It's claimed that, the replacement of the conventional image intensifying screens in X-ray cassette with the rare earth screens has been shown to reduce patient dose to half or more which will increase the tube life in a very cost effective manner [16-18].

Therefore this work has been carried out to evaluate collective dose of the patients as a result of radiation dose from diagnostic X-rays, and to estimate the annual effective dose per patients which could be reduced by half using rare earth intensifying screens.

Methodology

The annual collective dose of patients from different X-ray diagnosis has been computed using the annual frequency and the mean effective dose of each type of X-ray examination. Data on the number of diagnostic procedures using X-ray examination in year 2010 in one Governmental and four corporate Hospitals by body site were collected in the Visakhapatnam, India.

The Hospitals included in the study were Government $_{KG,}$ Private $_{C'}$ Private $_{LC,}$ Private $_{NC,}$ and Private $_{MW}$. These hospitals were chosen for the study because they are the largest hospitals in the Visakhapatnam in terms of workload due to large number of patients attending to them. The study subjects included were all diagnostic X-ray examination in year 2010. The study was retrospective study design. The questionnaires to request the number of diagnostic X-ray examination together with the corresponding patients during one year period were sent to the respective hospitals. The data was collected by table format which helps to register the number of X-ray examination and number of patients in the specified period by body site.

The annual collective effective doses were obtained by multiplying the average effective dose per patient by the number of people exposed to a given source of ionizing radiation. In general, the per caput effective dose is obtained by dividing the collective dose with the number of inhabitants, but against to this in the present study the effective dose per patient has been evaluated by dividing the collective dose with the number of patients.

Effective dose is a valuable parameter for comparing risk arising from different radiation sources but its precise determination is complex one. It cannot be measured directly. A practical approach starts from entrance surface dose (ESD) or dose–area product (DAP) measurements and uses dedicated conversion coefficients. In the case where a region is not able to make extensive patient dose measurements to estimate representative effective doses for all types of X-ray examination, it is usual practice to use published values from the literature [12]. Hence, since there is no study available for Visakhapatnam, India, to estimate the average effective dose per examination, in the present study the average effective dose per examination per body site has been taken from Supe et al. [11].

Results

The total number of diagnostic X -ray examination in the 5 hospitals were 46,350 (1.28/patient) on a total of 38,322 patients. The examination included in the study are all plain radiographs

Body site	New care	Care	KGH	Manepal	Lion Cancer	Total examinations
Chest	2673	11099	1400	482	200	15854
cervical spine	1145	496	2000	482	200	4323
Thoracic spine	1720	59	1800	484	100	4163
Lumbar spine	245	208	6200	434	100	7187
Skull	128	314	1650	362	150	2604
Abdomen	111	634	2470	452	50	3717
pelvis and hip	243	86	5280	330	700	6639
Ba meal	0	0	130	12	0	142
Baenema	0	0	70	12	0	82
Ba follow	0	0	80	28	1200	1308
IVU	0	121	186	24	0	331
Total	6265	13017	21266	3102	2700	46350

Table 1: Total diagnostic x-ray examination in five selected Visakhapatnam hospitals in year 2010.

Body site	Effective dose (mSv) per exam	Total number of examination	Total number of examination	%of examination out of total	Total collective dose (man.Sv)	% collective dose out of total
Chest	0.1	15854	15186	34.20	1.58	3.22
cervical spine	0.27	4323	3436	9.33	1.16	2.37
Thoracic spine	1	4163	3254	8.98	4.16	8.46
Lumbar spine	1.9	7187	4962	15.50	13.65	27.76
Skull	0.33	2604	2085	5.62	0.85	1.74
Abdomen	1.5	3717	3017	8.02	5.5	11.33
pelvis and hip	0.9	6639	4858	14.32	5.97	12.14
Ba meal	7.7	142	56	0.31	1.09	2.22
Baenema	8.6	82	41	0.18	0.71	1.43
Ba follow	10	1308	1234	2.82	13.08	26.59
IVU	4	331	193	0.71	1.32	2.69
Total		46350	38322			

Table 2: Total examination and collective dose of due to some diagnostic x-ray examination in five selected Visakhapatnam hospitals (2010).

(conventional film-screen radiography and conventional radiography), Intravenous urography (IVU) and barium studies.

As Table 1 and Table 2 shows, in Government $_{KG}$ hospital which is the largest Governmental hospital of north coastal districts of Andhra Pradesh State, the number of diagnostic X-ray examination were highest 21,266 (45.92%). In addition to this, in Government $_{KG}$ all the variable diagnostic examinations included in the study were performed. Private C, and Private NC hospitals followed Government $_{KG}$ having total examination of 13,017 (28.1%) and 6,265 (13.52%) respectively. The least number of diagnostic examinations done in Private $_{LC}$ Hospital were 2,700 (5.8%). Of all hospitals, Barium meal and Barium enema were done only in Government $_{KG}$ and Private $_{MW}$ hospitals.

The total estimated collective dose to all patients from diagnostic plain X-rays, Intravenous urography and Barium studies was 47.3man. Sv (1.23 mSv/patient) (Table 2). Out of a total of 46,350 radiography exposures taken in five Hospitals chest accounted for 15,854 (34%). Due to its low effective dose per examination it only accounted for 1.585 manSv (3.35%) of the total annual collective dose (Table 2).

Lumbar spine and Barium follow accounted 13.65 man.Sv (28.88%) and 13.08 manSv (27.67%) of the total annual collective dose having annual exposure of 7,187 (15.51%) and 1,308 (2.82%) respectively. Barium tests (Ba meal, Ba enema, and Ba follow) which were performed only in three hospitals (Government $_{KG}$, Private $_{LC}$, Private $_{MW}$) accounted for 3.3% of all examination that resulted for 14.88 man.Sv (30.25%) of the total collective dose which is significant due to their high effective dose per examination (Table 1 and Table 2).

Discussion

The annual collective dose received from diagnostic radiology in year 2010 in five Hospitals in Visakhapatnam is 47.3 man.Sv (1.23 mSv/patient). This average radiation dose received per patient (1.23 mSv/patient) is less than that of Luxembourg (1.83 mSv/caput) but higher than that of the average radiation dose received per patient for the Ethiopian populations (0.42 mSv/patient) [5]. In this study the higher value of mean effective dose to patient is explained by the fact that, out of a total of 46,350 exposures taken in five hospitals, Barium tests which have the highest effective dose accounted for 14.88 man.Sv (30.25%) of collective dose which results in 3.30% of examination. The peculiarity of Ba follow is the high dose to the patients, individual dose for one examination being approximately taken 10 mSv [12]. Therefore, even if the number of Barium follow examination is small 1,308 (2.82%) they can contribute considerably to the population collective dose 13.08 man.Sv (27.67%). According to European commission radiation protection No. 154 report, the population effective per caput dose in 10 European countries was between 0.38-1.83 mSv [11]. According to this report UK's per caput dose is lowest while that of Luxembourg is the highest. In Luxembourg the study shows the average effective dose per caput has steadily increased from 1.47 mSv to 1.83 mSv from 1994 to 2002 respectively. The contribution of computed tomography has risen from 0.48 mSv to 0.99 mSv for the same period [12]. The value obtained in this study corresponds to the Europeans values.

Estimation of the extent of the risk on the basis of the annual number of diagnostic X-rays undertaken in the UK and 14 other developed countries were done. Their result indicate that in the UK about 0.6% of the cumulative risk of cancer to age 75 year could be attributable to diagnostic x-rays [6]. This 0.6% percentage is equivalent to about 700 cases of cancer per year. In other 13 developed countries estimates of the attributable risk ranged from 0.6 to 1.8%, whereas in Japan which had the highest estimated annual exposure frequency in the world, it was more than 3% [2,5]. While in the research done on Israeli population in 1998 [14], their result shows 93 cases of incidence of cancer will be induced due to diagnostic X-ray examination after some latency period. Similarly in the study done on Yazd population (Iran) in the year 2010 to evaluate the cancer risk of radiation dose arising from coronary angiography examinations was found to be 239 fatal cancers per million populations [4].

Although effective dose can be used to enable comparison of relative detriment between procedures that utilize ionizing radiation, it should not be used retrospectively to determine individual risk [3,4,10]. Individual risk is best evaluated by determining the mean doses to all radiosensitive tissues of the individual and combining these with age-, sex-, and organ-specific risk coefficients [19-24]. In the present study effective values presented for various examinations are taken from the average effective dose calculated by Supe et al. [11], with the realization that for any examination, actual doses in practice may slightly vary by some order of magnitude. Consequently the present collective effective dose estimates for medical exposures are not used for assessing radiation risks (or detriment) to populations of patients by simple application of the nominal probability coefficients for radiation-induced cancer given by International Commission on Radiological Protection (ICRP) [19].

Currently only Private $_{MW}$ is using "rare-earth screens" for all the examinations, Private $_{C}$ hospital is following partially with rare-earth screens and the rest of the examinations are carried out with "tungstate" whereas all other Hospitals are following 100% the latter one. In this work it is found that 20% of examinations in hospitals are due to "rare-earth screens" and the rest 80% is due to "tungstate". For a given resolution, rare-earth screens allow at least a halving of the dose compared with that delivered using the old tungstate screens [14-16]. Assuming a 50% reduction in dose with rare-earth screens, there is a potential for reducing the conventional dose from radiography in the Visakhapatnam from 47.3 man.Sv to 39.34 man.Sv per year.

The reduction in radiation dose not only results in reduction in radiation associated cancer but also it prolongs the X-ray tube life. This is due to the fact that rare earth intensifying screens are faster than conventional screens resulting as a consequence of shorter exposure times. This dose reduction is related to the cumulative radiation quality emitted by the tube which will increase the tube life by around 60% [16,25].

Radiation exposure cannot be entirely avoided on this planet. The proper use of medical ionizing radiation can greatly benefit patients. A better understanding of medical ionizing radiation allows practitioners to better communicate the risks and benefits to their patients.

Although the use of ionizing radiation for diagnostic medical procedures is an acceptable part of modern medicine, there is also the potential for inappropriate use and unnecessary radiation dose to the patient, so the request of radiography must be justified. Radiologists and other physicians have an obligation to balance the risks and benefits of various medical procedures and to inform the patient [26-29].

An effort should be made to reduce the effective cumulative dose of Visakhapatnam patients. This can be done by reducing number of fluoroscopic examinations which take high radiation dose and replacing the radiological detectors that associated with conventional screen-film combinations with rare earth screen aided with computed or direct digital systems which are presently using in Private $_C$ and Private $_{MW}$ Hospitals. One of the largest reduction ways in radiation exposure may be to exclude the prescription of unnecessary or unproductive X-ray examination. Patient exposure can also be reduced by assuring that good radiographic technique is practiced. It was said that the fundamental objective of X-ray examination is to obtain optimum diagnostic information with minimum diagnostic exposure [14]. If this sort of transition is taken up by other hospitals then reduction of the patient cumulative doses in Visakhapatnam might take place significantly.

This study has limitations in terms of not evaluating the values of effective dose in the respective hospitals. Finally the authors of this manuscript recommend that the findings of the present work can be used as a baseline upon which future study should be done in a large scale in all hospitals including Computed Tomography in Visakhapatnam.

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