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ASSESSMENT OF RADIATION EXPOSURE OF DIAGNOSTIC X-RAYS AMONG PATIENTS AND PERSONNEL

BY

ALEMU TESFAHUN (B.SC.)

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DECLARATION

I the undersigned, declare that this thesis is my original work, has never been presented in this or any other university, and that all resources and materials used here in, have been duly acknowledge.

Name: Alemu Tesfahun, B.Sc.

Signature ___________________

Place: Addis Ababa University, Ethiopia

Date of submission: July, 2005

This thesis has been submitted for examination with my approval as a University advisor.

Name: Abera Kumie (MD, M.Sc)

Signature____________________

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List of abbreviations

CI: confidence interval

cm: centimeter

DNA: Deoxyribonucleic acid

ICRP: International Commission on Radiological Protection

Kg: Kilogram

kV: kilo voltage

kVp: kilo voltage peak

m: meter

mA: milliampere

mAS: milliampere-second

mGy: milligray

mm: millimeter

mSv: millisievert

NRPA: National Radiation Protection Authority

OPD: out patients department

OR: odd ratio

PA: Posterior- Anterior

SD: standard deviation

SPSS: Statistical Package for Social Science

Sv: sievert

TLD: Thermo luminescent dosimeter

Uk: United Kingdom

ABSTRACT

Background: Medical diagnostic radiation is manmade sources of exposure in medical practices. Ionizing radiation yields known health hazard that may vary from skin burn to cancer or death. In Ethiopia, health facilities are growing in number with the increasing facility of radiology services. However, the number of personnel, the provision of spare part of machine, quality assurance and other aspect has not grown with demand of safety.

Objectives: The study was designed to assess the status of radiation exposure due to diagnostic x-rays among patients and personnel.

Methods: Cross-sectional study was carried out in 43 functional diagnostic x-ray institutions from January to February 2005 in Addis Ababa. A total of 215 patients who were examined for chest posterior-anterior (PA) were randomly selected. In addition, all radiology personnel who had dose report of the year 2004 were the study subjects. National Radiation Protection Authority completed radiation surveillance and quality control records of institutions were also considered.

Results: The mean (SD) skin entrance dose of patients was 1.877(1.546) mSv. Out of the total 215 patients, 206(95.8%) of patients' shallow dose and 191(88.8%) patients entrance deep dose were greater than 0.4mSv. The annual mean (SD) skin entrance dose for radiology personnel was found to be 0.407(0.225) mSv. According to records analysis of the National Radiation Protection Authority quality control, 15(19.2%), 13(16.7%) and 17(21.8%) of institutions machines were deviated with in unacceptable range in their generator voltage, the machines timer and, their collimation and beam alignment respectively. Multi variate analysis indicated that exposure setting greater than 25mAS [OR= 3.141; 95% CI = (1.170-8.432)] had impact on patients' received dose to be high.

Conclusion: Adult patients examined for chest-PA entrance dose was abnormally high. Thus, great efforts will be expected from different sectors of the country in order to bring the patients received dose for specified radiological procedure to minimum level.

INTRODUTION

Since Ethiopia follows investment promoting policy, the establishment of medical facilities is growing in number and type. Medical applications using ionizing radiation for diagnostic purpose are part of those facilities. As a result, human resource, quality control, protective device supply, maintenance and support service ought to have grown with the increasing number of facilities. But the poor status of the country economy may have its impact on them.

Ionizing radiation is firmly established as an essential tool for diagnosis and therapy in medicine. The most widespread use of radiation in medicine remains diagnostic radiology which involves imaging with x-rays. A wide range of basic techniques is utilized including conventional radiography (static images captured on film loaded between intensifying screens in cassettes) and fluoroscopy (dynamic imaging with an (electronic) image intensifier) (1).

The use of ionizing radiation for medical diagnosis is widespread throughout the world. There are significant country-to-country variations in resources and practice in medical radiology. In general, medical exposures are confined to an anatomical region of interest and dispensed for specific clinical purposes so as to be direct benefit to the examined or treated individual patient. X-ray examinations characteristically involve partial body exposures and result in complex patterns of energy deposition. Such diagnostic exposures are in general characterized by relatively low doses to individuals that in principle are the minimum necessary for the required clinical information. Patient doses vary widely between different types of examination, with effective doses typically in the range from 0.1 to 20mSv although there are significant variations in practice for a given type of examination between individual patients and also different x-ray departments. Ionizing radiation is used increasingly in medicine, principally for diagnosis with an annual global total for 1996 of about 2.5 billion examinations (78% from medical x-rays, 21% from dental x-rays and 1% from nuclear medicine). The annual average dose to the world population from all diagnostic exposures has been revised from 0.3 to 0.4mSv per caput (1, 2).

The average level of occupational exposures is generally similar to the global average level of natural radiation exposure. However, a few percent of workers receive exposures several times higher than the average exposure to natural radiation. The exposure of workers is restricted by internationally recognized limits, which are set around 10 times the average exposure to natural radiation (2).

Health and health related indicators of 2002/03 showed that from 11,667,554 new OPD visited patients in Ethiopia, 210,016(1.8%); and from 678,548 new OPD visited patients in Addis Ababa, 29,857 (4.4%) patients administered x-ray diagnostic service. The benefit derived from the application of x-rays in medicine is indisputable; however, such applications must be made with prudence and with regard to minimize the exposure as low as reasonably achievable (3, 4, 5). In general, sources of radiation have been regularly controlled by National Radiation protection Authority of Ethiopia. Exposures to diagnostic x-rays are rarely known and documented in Ethiopia. Thus, this study is designed to assess radiation exposure of diagnostic x-rays among patients and personnel.

LITERATURE REVIEW

The annual global caput effective dose due to natural radiation sources is 2.4mSv. However, the range of individual dose is wide. In any large population about 65% would be expected to have effective doses between 1mSv and 3mSv, about 25% of the population would have annual effective doses less than 1mSv and 10% would have annual effective doses greater than 3mSv (2).

Current estimates put the world wide annual number of diagnostic exposure at 2500 million. Some 78% of diagnostic exposures are due to medical x-rays and chest examinations remain the most common procedure. The annual collective dose from all diagnostic exposures is about 2500million man-Sv, corresponding to a worldwide average of 0.4mSv per person per year. The average radiation exposure of population in Russia is calculated in 2001 as about 330,000 man-Sv from natural and about 4200 man-Sv from all others sources. There are, however, wide differences in radiological practice throughout the world, the average annual per caput values for states of upper and lower health care levels being 1.3mSv and 0.02mSv, respectively. The guidance level of dose for diagnostic radiography for a typical adult patient entrance surface dose for chest-PA is 0.4mGy (1, 6, 7, 8).

Several authors have suggested recording of radiologic techniques factors (kilo voltage peak, milliamper, time, focus-skin distance, etc.) and calculating doses from measured radiation out puts. Alternatively, doses may be measured using thermo luminescent dosimeters (TLDs) or photographic film placed on the patient's skin. Otherwise, without the use of monitoring equipment, humans are not able to “find” ionizing radiation. In contrast to heat, light, food, and noise, humans are not to see, taste, smell, or hear ionizing radiation (9, 10).

The technique uses 60-75 Kvp and chest stand without grid; this is good for imaging the soft tissue in the lungs. For this technique the average skin entrance dose measured was 0.16mGy with a range of 0.01mGy (the minimum dose measurable) to 0.88mGy. The second technique utilizes 120-130Kvp and a high factor grid in the chest bulky. The departmental average skin doses varied from 0.04mGy up to 0.49mGy. The UK National Radiation Protection Board guideline dose for PA chest is 0.3mGy (11).

For high-Kvp charts, the Kvp selected would generally be greater than 100. High-Kilo voltage exposure techniques are ideal for barium. This type of exposure technique could also be used for routine chest radiography to provide improved visualization of the various tissues densities presents in the lung fields and mediastinum. Lower, or more conventional, Kvp settings provide increased subject contrast between bone and soft tissue, whereas when 120 Kvp, for example, is selected for chest radiography, all skeletal tissue will be penetrated and exhibit increased visualization of the different soft tissue densities present (4).

When ionizing radiation passes through matter, energy imparted to the matter as ions are formed; the energy imparted is quantified in terms of dose. In biological tissues, the process of changing atoms through ionization also changes the molecules of those atoms and it may thus cause damage to the cells containing those molecules (12).

Thus, when ionizing radiation penetrates living tissue, it can destroy living cells or make them function abnormally. It does this by physically removing an electron from water molecules in the cell converting them to free radicals. These in turn break the DNA chain or scramble its coding. Although most chromosomes repair normally, impaired chromosome coding may continue if mitosis occurs before the repair process. The cells that are least differentiated and multiply the most rapidly are the most radiosensitive. Alternation of DNA in cells can leads to cancer, genetic mutation, or direct tissue death. In UK about 0.6% of the cumulative risk of cancer to age 75 years could be attributing to diagnostic x-rays. This percentage is equivalent to about 700 cases of cancer per year. In 13 other developed countries estimates of the attributable risk ranged from 0.6% to 1.8%, where as in Japan, which had the highest estimated annual exposure frequency in the world, it was more than 3% (13,14).

Ionizing radiation is able to produce a unique type of damage in which multiple lesions are encountered with in close spatial proximity. Even a single track through a cell is likely to induce these unique clustered damages. This type of damage may not be generated frequently endogenously or by other exogenous agents, and thus, there may not have been a strong selective pressure driving efficient repair. Although cells have a vast array of damage response mechanism that facilitate the repair of DNA damage and the removal of damaged cells, these mechanism are not fool proof. Moreover, clustered radiation- induced lesions pose a particular problem and current emerging evidence suggests that closely spaced lesions can compromise the repair machinery. On this basis, there is mot any strong evidence for a radiation dose below which all radiation dose below which all radiation- induced damage can be repaired with fidelity (15).

Cancer initiation risk estimates are strongly dependent on the profile of dose-response curve. The most simple assumption is the linear model in which the risk is directly proportional to dose. In this theory, a single particle of radiation striking a single DNA molecules initiates cancer. Hence, the probability of cancer initiation is proportional to the number of the particle interactions, which in turns is proportional to the dose received. In typical medical x-ray, it is reasonable to assume that over a defined cross-section of human tissue, millions of x-ray photons are passing through a thickness containing millions of cells. One would therefore expect that there is a finite probability that a number of collisions and interactions will occurs. There is evidence, however, that radiation-induced cancer may often be at least a two-hit process. There must therefore be at least two interactions occurring with in a cell nucleus in which free electrons are produced and cell damaged occurs. The two interactions may be caused by the same photon or by two different photons. In the first case, the linear model described above is valid. In the second case, the risk, R, is proportional to the dose, i.e. $R \infty D^2$. Both possibilities are accounted for in the quadratic model given by: $R= \alpha D + \beta D^2$. The critical dose for which the two terms are equal in magnitude can be deduced from the mean path length between interactions for the particle and the diameter of the cell nucleus (16).

According to the Linear-No-Threshold Debate in Radiation Protection, health regulations to limit occupational exposures to ionizing radiation are based on the philosophy that any dose of radiation, no matter how small, might cause cancer. Any exposure is harmful and one can calculate the probability of cancer from a linear extrapolation of observed cancer at high radiation exposure. This Linear-No-Threshold (LNT) theory has led to the widespread belief that there is no safe dose of radiation and that regulations should establish exposure limits as low as possible if not zero (17).

Diagnostic x-rays are the largest manmade source of radiation exposure to the general population, contributing about 14% of total world wide exposure from manmade and natural sources. However, although diagnostic x-rays provide great benefits, that their use involves some risk of developing cancer is generally accepted. The risk to an individuals is probably small because radiation doses are usually low (typically <10mGy), but the large number of people exposed annually means that even small individual risks could translate into a considerable number of cancer cases (14).

There are basically two requirements in setting the dose limit. The first is to keep doses below the threshold level for deterministic effects and the second is to keep the risk of stochastic effects at an acceptable level. For occupationally exposed persons, the ICRP recommends a limit on effective dose of 20mSv per year, averaged over five years, with the further provision that the effective dose should not exceed 50mSv in any single year(8).

The mean annual dose of diagnostic radiology of 626 staff during five year period (1998-2002) in Saudi Arabia is in the range of 0.48-0.94mSv (all monitored workers) and 1.38-2.56mSv (measurably exposed workers).The radiologic technologists working in the United State, the estimated population mean badge dose declined more than 40-fold, from 100mSv per year from before 1940 to about 2.3mSv per year during 1977-1984. The overall population mean badge dose for hospital workers declined about 75% from the 1930s to the decades of the 1940s and

1950s. There was another 80% decline in the annual dose from about 28mSv (on average) in the 1950s to about 3.6mSv during the 1960-1976 periods (18, 19)

In Sudan, the number of x-ray diagnostic machines exceeds 400. As observed in the occupational exposure records, the highest average annual dose recorded for industrial application in 1999 was 4.17mSv while the lowest one was 0.392mSv in research field. For nuclear medicine, radiotherapy and x-ray diagnostic radiology the average annual dose was 0.880, 0.697 and 0.536mSv respectively. As result, the average individual annual dose in different applications is less than 1mSv per year except for the workers in industrial radiography, only 12 radiation workers (3.64%) received doses exceeding 1mSv and no individual approaches the dose limit of 20mSv recommended by the ICRP and set by Sudan's regulation (20).

National Radiation Protection Authority of Ethiopia final report on situational analysis of diagnostic x-ray institutions in 2002 indicated that there were 243 institutions registered in the country, Ethiopia. The result of the assessment of the 167 institutions revealed that 51 of them (31%) were in good standards, 65 of them (36%) were with in acceptable standards but there was still room for improvement, 41 of them (25%) required regular follow up and communication to up grade their standards and 10 of them (6%) were far below the standard (21).

Study report from Tikur Anbessa Referral Hospital Radiology Department on Skin Entrance Dose to hundred adult patients from routine P-A chest X-ray using Lithium fluoride pellets

TLDs indicated that the average skin entrance dose was 1.24 mGy, ranging from 0.68 to 1.98 milligray /mGy/. Sixty four percent of the patients had chest x-ray exposure already. The mean body mass index (BMI) was found to be 21.3, ranging from 12.96 to 29.00 (22).

A study conducted by Teshome Bayou on levels of doses to radiological workers in Ethiopia during the period 1977 to 1988 revealed that the annual average radiation dose exposure to the radiation workers monitored by film badges was 1.44mSv whereas for those monitored by TLDs was 4.51mSv with corresponding collective dose equivalents of 0.29 and 4.51man-Sv respectively. In 1985, the TLDs resulted in peak value of 5.40mSv; this is accountable by the technical difficulties which are likely to occur when new method is just introduced. The annual dose level received by radiological workers is much lower than the internationally recommended values of 50mSv but it is relatively higher than values for similar workers in other countries (23).

Implication of the study

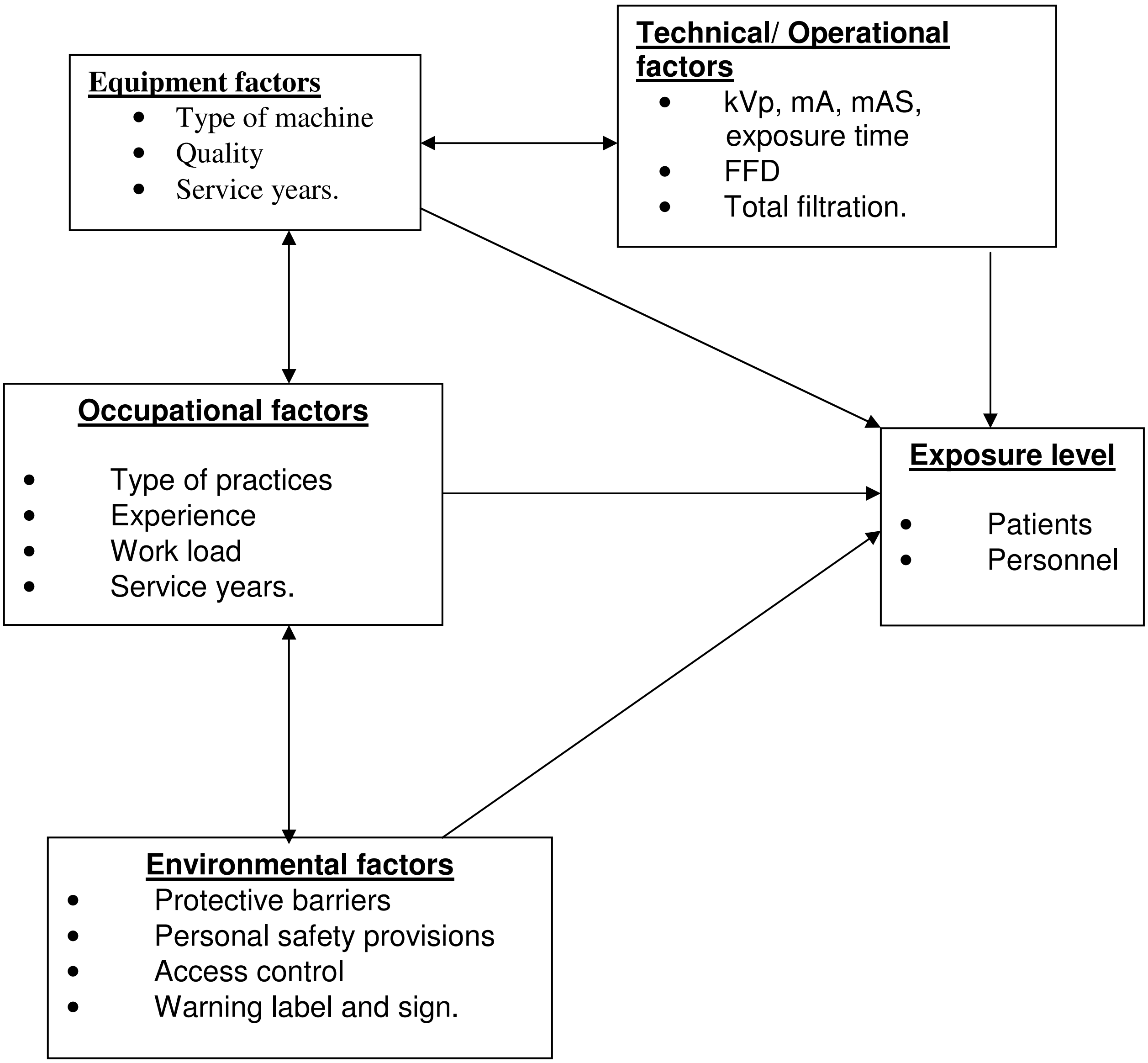
The diagnostic x-ray exposure of the population in Ethiopia is one of the most important types of radiation to be essentially assessed among all kinds of radiation because of its magnitude and adverse effect if not delivered with precautions. It is clear that patients who examined for chest-PA get a certain amount radiation exposure during examination from diagnostic x-rays. This exposure of radiation ought to be as low as reasonable achievable with out compromising the diagnostic value of the patient. In considering the strategy for the reduction of radiation exposure, the level of the exposure should be identified. This may show the magnitude of the problem and leads to look for possible solutions accordingly.

The problem even extends to the personnel who work in radiology department. Exposure levels of both the patients and personnel are affected by different factors as shown in conceptual model (Figure 1).Since chest x-ray examination is common practice and due to time constraint, the study has focused on chest x-ray. In this study, it is tried to evaluate radiation exposure of diagnostic x-rays among patients who examined for chest-PA and personnel in Addis Ababa. Different institutions are considered for the study which helps to pick the variation. Such study is necessary for the evaluation of the efforts that have made by the National Radiation Protection Authority and may be used as baseline for planning the necessary actions to minimize the radiation exposure in diagnostic radiology.

Conceptual model

A conceptual model for diagnostic x-rays radiation exposure of patients and personnel was developed after referring literatures and consulting experienced professionals. In fact, many factors affect the exposure level of patients and personnel. In the conceptual model four major factors are identified and categorized systematically according to their relationships among themselves and their effect to the exposure. Primarily, in diagnostic x-rays exposure related with the functioning of the machine which is mainly affected by the type and quality of the machine. On operation, technical parameters are adjusted according to the required examination for a patient. These are mainly under the control of the personnel. Hence, the experience of the personnel plays a lot. In addition, proper protective barriers and safety provisions should be available to reduce to practically achievable the radiation exposure of both patients and personnel (Figure 1).

Figure 1: Conceptual Frame Work for Diagnostic X-ray Radiation Exposure



Note: Patients exposure is mainly affected by technical factors and equipment factors but personnel exposures are mostly affected by occupational factors and environmental factors.

OBJECTIVES

GENERAL OBJECTIVE: to assess radiation exposure due to diagnostic x-rays among patients and personnel in Addis Ababa.

SPECIFIC OBJECTIVE:

1- To evaluate patients' dose received from diagnostic x-ray applications.

2- To assess personal dose for radiology personnel.

3- To study factors determining the level of exposure.

METHODS AND MATERIALS

Study design: Institutional based cross-sectional study where used to evaluate the level of exposure patients and factors affecting its level.

Study area

The study area was Addis Ababa. Addis Ababa is the capital city of the Federal Democratic Republic of Ethiopia and is the center of political, social and cultural activities of the country. There are 22 hospitals with 2,346 beds, 28 health centers, 148 health stations, 46 health posts and 117 diagnostic x-ray institutions in those health facilities in the city (3, 24). Eighty-four x-ray units were functional at the time of this study.

Source and Study population: The source populations were patients and radiology personnel who have worked in 84 functional diagnostic x-ray health institutions in Addis Ababa.

Inclusion criteria: Adult patients who were examined for radiological procedure of chest posterior-anterior (PA) in those institutions from January to February 2005. In addition, all radiology personnel who had dose reports in year 2004 and quality assurance records of functional institutions were considered for the study.

Sample size determination

The required sample size of patients was determined using the formula for single population proportion:

$$n= (z\ \alpha/2)^2 * p\ (1-p)/d^2$$

The following assumptions were considered: Where “n” was the required sample size, ”Z” was a standard score corresponding to 95% confidence level; ”p” was assumed over exposure to diagnostic x-rays, 85% which was derived after having a pilot test in 17 institutions; “d” was the margin of error of 5% and non-response rate of 10% was considered . Thus, the required sample was calculated to be 215 patients.

Sampling technique

The first five voluntary patients who satisfied the inclusion criteria from the study institutions were randomly included in the study to fit the limited supply of TLDs and its analysis. TLDs were reused immediately after reading dose results and annealing in the laboratory.

Data Collection Procedure

Patients:

Dependent variable was exposure level to diagnostic x-rays. Independent variables were socio-demographic characteristics such as age, sex, body mass index and type of institution; radiological techniques variables such as film focus distance (FFD), kilo voltage (Kv), exposure setting (mAS), millamper (mA), and exposure time (Sec). Based on the list of functional institutions obtained from Regulatory Control Department of National Radiation Protection Authority; consent was asked from concerned officials of the study institutions. After obtaining consent, the principal investigator sat with radiologist and radiographers to provide orientation on objective of the study, how to choose study patients, fill the patient data form, and how and where to place the TLDs on patient's skin. Lithium Fluoride TLDs chips assembled in bar coded cards used for collecting patients' dose during examination with diagnostic x-rays. Thirty TLDs were obtained from National Radiation Protection Authority for this study. This was not sufficient number. Five TLDs were distributed for each institution. TLD bar coded cards for patients placed on patient's skin at the center of the entrance primary x-ray beam axis by radiographers prior to the exposure x-ray. The code of the TLD bar was entered in the patient's data request form. The completed patients' data request form and their TLDs were collected. TLDs were taken to the National Radiation Protection Authority laboratory for reading. Harshaw TLD Reader Model 4500 was used for TLDs analyzing. The analyzed TLDs were annealed and distributed for other institutions.

Personnel dose

The monthly dose reports of Thermo luminescent Dosimeter (TLD) of all monitored radiology personnel in Addis Ababa of the year 2004 were collected from data base of the TLDs processor and compiled in code number excluding their personal and institutional names from National Radiation Protection Authority. Then, personnel dose reports were identified by their sex, professions and type of institutions.

Quality Control Records

Radiation surveillance and quality controls were formally done in each institution for compliance with regulatory requirement by National Radiation protection Authority.

Photocopies of completed radiation surveillance and quality control records were obtained from the Authority for the period of January 2004 to February 2005 in confidential manner.

Data quality assurance

The National Radiation Protection Authority would carry out annually sensitivity check of TLDs under a controlled set of standard. Survey meters that were used by National Radiation Protection Authority were calibrated by International Atomic Energy Agency personnel from Vienna. After developing questionnaire, experienced professionals were asked to check the relevance. Completed questionnaires were checked according to predesignated specification by the principal investigator and error corrected. The completed patients' questionnaires, annual of radiology personnel dose reports and quality assurance records data entry were processed by EPI Info. Version 6 computer program. Then, the entered data were checked for consistency and completeness.

Operational Definition

Collective dose: the product of the number of individuals exposed to a source and their average radiation dose. The collective dose is expressed in man-sieverts (man-Sv) (8).

Shallow dose: the dose equivalent at depth of 0.07mm for weakly penetrating radiation (8).

Deep dose: the dose equivalent at depth of 10mm for strongly penetrating radiation (8).

Data Analysis

Data were analyzed by computer programs of EPI Info version 6 and SPSS version 11. Descriptive statistics were used to describe data quantitively. For comparing the statistical difference between the means, t-test was used and for three means, ANOVA was applied. Odds ratio was used to look for association between variables. Multivariate analysis using binary logistic regression and multiple linear regression models were computed to study the nature and strength of the relationship between dependent and independent variables. For binary logistic regression due to the effect of extreme values, median were taken as cut off point to dichotomize tube exposure setting and voltage; beside method of forward LR using probability of entry of 0.25 and removal of 0.30 were applied. For multiple linear regression, deep dose data transformed with log with base 10 was computed to improve the skewness of data distribution. The outliers were detected using stem and leaf plot, box plot and histogram with normal line curve, and selected out from the analysis. In addition, forward method with probability of entry of 0.25 and removal of 0.30 were used.

Ethical considerations

The Department of Community Health, Faculty of Medicine of Addis Ababa University approved the research proposal. The approval letters were submitted to institutions concerned officials to get their consent. Further more, verbal consent was requested from each patient. Consent was asked from National Radiation Protection Authority get personal dose reports of the year 2004 and completed radiation surveillance and quality records of diagnostic x-rays service of the institutions of Addis Ababa.

Communication of Results

The findings of this study will be disseminated to Radiologist Association, Radiographers Association of Ethiopia, National Radiation Protection Authority and relevant bodies including

Addis Ababa University. This will be done through submission of reports and presenting findings at appropriate seminars, workshops and conferences. Besides publication of the study findings on the local /international journal will be considered.

RESULTS

Patients' entrance dose

Out of 84 health institutions functional at the time of the study, 43 health institutions were covered in the study of patients' entrance dose of chest-PA. A total of 215 patients were included in the study from those institutions which made the response rate 100%. Of these patients, 60(27.9%) were government health institutions and 155(72.1%) were from private health institutions.

Socio-demographic characteristic of patients

Out of 215 patients, 116(54.0%) were males and 99(46.0%) were females. The mean (SD) age of patients was 35.7(14.8) year. 67(31.1%) of patients were with age greater than 39 years and 55(25.6%) of patients were less than 25years.The mean (SD) entrance skin dose and deep dose per radiograph of adult patients examined for chest–PA were found 1.877(1.546) mSv and 1.340(1.109) mSv, respectively. Of the total, 206(95.8%) patients entrance shallow dose and 191(88.8%) patients entrance deep dose were greater than 0.400mSv of the guidance level of diagnostic x-rays for chest –PA of entrance surface dose (Table 1). Half of the patients (50.2%) had exposure to diagnostic x-rays before the study with in range of one to nine times.

Table1: Age, sex distribution and entrance dose per radiograph of adult patients examined for chest-PA in health institutions in Addis Ababa, January-February, 2005.

Variable	Frequency (n=215)	Percent (100.0)
Age group in year		
<25	55	25.6
25-29	41	19.1
30-34	22	10.2
35-39	30	14.0
>39	67	31.1
Mean(SD)	35.7(14.8)	
Sex		
Male	116	54
Female	99	46
Shallow dose, in mSv		
<0.200	3	1.4
0.200-0.400	6	2.8
0.401-0.600	14	6.5
0.601-0.800	22	10.2
0.801-1.000	16	7.4
>1.000	154	71.6
Mean(SD)	1.88(1.55)	
Deep dose, in mSv		
<0.200	3	1.4
0.200-0.400	21	9.8
0.401-0.600	28	13.0
0.601-0.800	18	8.4
0.801-1.000	20	9.3
>1.000	125	58.1
Mean(SD)	1.34(1.11)	

Table 2: Age by sex of patients examined for chest-PA in health institutions in Addis Ababa, January-February 2005.

Age group in years	**Sex**		**Total**
	Male	**Female**	
<25	25(11.6%)	30(14.0%)	55(25.6%)
25-29	21(9.8%)	20(9.3%)	41(19.1%)
30-34	14(6.5%)	8(3.7%)	22(10.2%)
35-39	18(8.4%)	12(5.6%)	30(14.0%)
>39	38(17.7%)	29(13.5%)	67(31.2%)
Mean age (SD)	36.8(14.61)	34.3(14.90)	
Total	116(54.0%)	99(46.0%)	215(100.0%)

From the total 215 patients, 67(31.2%) patients were age greater than 39 years. The mean (SD) of age of males and females were 36.8(14.61%) and 34.3(14.90%) years respectively (Table 2).

Table3: Entrance dose by sex of patients examined for chest-PA in health institutions in Addis Ababa, January-February 2005.

Shallow dose group in mSv	**Sex**		**Total**
	Male	**Female**	
<0.200	1 (0.5%)	2 (0.9%)	3 (1.4%)
0.200-0.400	3 (1.4%)	3 (1.4%)	6 (2.8%)
0.401-0.600	11 (5.1%)	3 (1.4%)	14 (6.5%)
0.601-0.800	12 (5.6%)	10 (4.8%)	22 (10.2%)
0.801-1.000	7 (3.3%)	9 (4.2%)	16 (7.4%)
>1.000	82 (38.1%)	72 (33.5%)	154 (71.6%)
Mean dose (SD)	1.909 (1.207)	1.841 (1.872)	
Total	116 (54.0%)	99 (46.0%)	215 (100.0%)
Deep dose group in mSv			
<0.200	1 (0.5%)	2 (0.9%)	3 (1.4%)
0.200-0.400	12 (5.6%)	9 (4.2%)	21 (9.8%)
0.401-0.600	17 (7.9%)	11 (5.1%)	28 (13.0%)
0.601-0.800	10 (4.7%)	8 (3.7%)	18 (8.4%)
0.801-1.000	8 (3.7%)	12 (5.6%)	20 (9.3%)
>1.000	68 (31.6%)	57 (26.5%)	125 (58.1%)
Mean dose (SD)	1.343 (0.852)	1.338 (1.355)	
Total	116 (54.0%)	99 (46.0%)	215 (100.0%)

Majority of male patients and most of female patients' entrance surface dose were above 1.000mSv. There was no a statistically significant difference in shallow dose between males and females (P value= 0.748). Similarly, most of male and female patients entrance deep dose were above 1.000mSv (Table 3).

Table 4: Entrance dose by institution of patients examined for chest-PA in Addis Ababa, January-February 2005.

Shallow dose group in mSv	**Institutions**		**Total**
	Government	**Private**	
<0.200	2 (0.9%)	1 (0.5%)	3 (1.4%)
0.200-0.400	4 (1.9%)	2 (0.9%)	6 (2.8%)
0.401-0.600	2 (0.9%)	12 (5.6%)	14 (6.5%)
0.601-0.800	1 (0.5%)	21 (9.8%)	22 (10.2%)
0.801-1.000	1 (0.5%)	15 (7.0%)	16 (7.4 %)
>1.000	50 (23.3%)	104 (48.4%)	154 (71.6%)
Mean(SD) dose	2.451(2.334)	1.655(1.028)	
Total	60 (27.9%)	155 (72.1%)	215 (100.0%)
Deep dose group in mSv			
<0.200	2 (0.9%)	1 (0.5%)	3 (1.4%)
0.200-0.400	4 (1.9%)	17 (7.9%)	21 (9.8%)
0.401-0.600	3 (1.4%)	25 (11.6%)	28 (13.0%)
0.601-0.800	1 (0.5%)	17 (7.9%)	18 (8.4%)
0.801-1.000	3 (1.4%)	17 (7.9%)	20 (9.3 %)
>1.000	47 (21.9%)	78 (36.3%)	125 (58.1%)
Mean(SD)	1.798 (1.675)	1.164 (0.723)	
Total	60 (35.7%)	155 (72.1%)	215 (100.0%)

From government institution, 54(90%) adult patients examined for chest-PA entrance surface dose per radiograph were greater than 0.4mSv; whereas from private institutions, 152(98.1%) patients entrance surface dose per radiograph were greater than 0.4mSv. The mean (SD) entrance surface dose for government and private were 2.451 (2.334) mSv and 1.581 (1.049) mSv, respectively. There was a statistically significant difference in entrance surface dose between government and private institutions (P value =0.013). The mean (SD) entrance deep dose for government and private were 1.798 (1.675) mSv and 1.164 (0.723) mSv, respectively (Table 4). There was a statistically significant difference in entrance deep dose between government and private institutions (P value=0.006). The mean (SD) of tube potential (Kv) was 69.2 (11.9). The mean (SD) film focus distance (FFD) was 144.6 (14.3) cm.

Table 5: Body mass index (BMI) by sex of patients examined for chest-PA in Addis Ababa, 2005.

Body mass index (kg/m²)	**Sex**		**Total**
	Male	**Female**	
≤ 17	6 (2.8%)	4 (1.9%)	10 (4.7%)
17.01-19.00	13 (6.0%)	8 (3.7%)	21 (9.8%)
19.01-21.00	38 (17.7%)	20 (9.3%)	58 (27.0%)
21.01-23.00	20 (9.3%)	30 (14.0%)	50 (23.3%)
23.01-25.00	15 (7.0%)	14 (6.5%)	29 (13.5%)
25.01-27.00	16 (7.4%)	9 (4.2%)	25 (11.6%)
>27.00	8 (3.7%)	14 (6.5%)	22 (10.2%)
Mean(SD) BMI	22.1(3.5)	22.8 (4.3%)	22.4 (3.9%)
Total	116 (54.0%)	99 (46.0%)	215 (100.0%)

31(14.5%) patients had body mass index (BMI) less than and equal to 19.00. About 137(63.8%) patients' BMI were with in the range of 19.01 and 25.00.The rest, 47(21.8%) patients' BMI were greater than 25.00 (Table 5). The mean (SD) patients' BMI was 22.4(3.9).Fifty five (25.6%) patients and 50(23.3%) patients in BMI categories of 19.01-21.00 and 21.01-23.00 were received entrance surface dose greater than 0.400 mSv.

Table 6: Logistic regression results to determinant factors for entrance dose of patients examined for chest-PA in health institutions in Addis Ababa, January-February 2005. (n=215)

Variable	**Deep dose in mSv**		**OR, 95% CI unadjusted**	**OR, 95% CI adjusted**
	≤ 0.4	**> 0.4**		
Voltage				
≤ 70Kv	21(9.8%)	119(55.3%)	4.235 (1.220, 14.703)	0.229 (0.065, 0.805)*
> 70Kv	3 (1.4%)	72(33.5%)	1.0	1.0
Exposure setting				
≤ 25mAS	18(8.4%)	99(46.0%)	1.0	1.0
> 25mAS	6(2.8%)	92(42.8%)	2.788 (1.060, 7.329)	3.141 (1.170, 8.432)
BMI				
≤ 25Kg/m2	21(9.8%)	147(68.4%)	2.095 (0.597, 7.355)	0.446 (0.127, 1.677)
> 25Kg/m2	3(1.4%)	44(20.5%)	1.0	1.0

Note: * P value < 0.05.

The applied voltage less than or equal to 70Kv [OR = 0.229; 95% CI = (0.065, 0.805)], the exposure setting greater than 25mAS [OR = 3.141; 95% CI= (1.170, 8.432)] and BMI less than or equal to 25Kg/m^2 [OR= 0.446; 95% CI = (0.127, 1.677)] (Table 6).

Table7: Multiple linear regression results to determinant factors for deep dose of patients examined for chest-PA in health institutions in Addis Ababa, January-February 2005. (n=169)

Variable	**β, 95% CI unadjusted**	**β, 95% CI adjusted**
Voltage(kV)	0.004 (0.001, 0.008)**	0.009 (0.005, 0.014)**
Exposure setting(mAS)	0.001 (0.006, 0.015)*	0.003 (0.000, 0.007)*
BMI(kg/m²)	0.015 (0.002, 0.028)*	0.009 (-0.003, 0.021)

Note: * P value < 0.05, ** P value < 0.005

Personnel dose

A total of 276 confidential radiology personnel dose reports of the year 2004 were collected from National Radiation Protection Authority.

Table 8: Type of institutions, sex and personnel who had personnel dose reports of the year 2004 in Addis Ababa, 2005.(n = 276)

Variable	Frequency	Percent
Type of institutions		
Private	147	53.3
Government	120	43.5
NGOs	9	3.3
Total	276	100.0
Type of personnel		
Radiographer	145	52.5
Radiologist	52	18.9
Others	79	28.7
Total	276	100.0
Sex		
Male	203	73.6
Female	73	26.4
Total	276	100.0

Note: These numbers could not indicate the existing personnel since these were extracted from the dose reports of personnel and not cross checked the existence of more than one dose report for the personnel due to strict confidentiality of the given data from NPRA.

147(53.3%) personnel dose reports were from private institutions and 120(43.5%) personnel dose reports were from government institutions. Almost half of the personnel dose reports were for radiographers. The category, others included dark room technicians, nurses, janitors and the likes who had worked in the radiology department. The majority dose reports were for males (Table 8).

Table 9: Personnel by sex of dose reports of the year 2004 collected of Addis Ababa from National Radiation Protection Authority, 2005.

Personnel	**Sex**		**Total**
	Male	**Female**	
Radiographer	130 (47.1%)	15 (5.4%)	145 (52.5%)
Radiologist	43 (15.6%)	9 (3.3%)	52 (18.8%)
Others	30 (10.9%)	49 (17.8%)	79 (28.6%)
Total	203 (73.6%)	73 (26.4%)	276 (100.0%)

As indicated in the above table most of the dose reports were for male radiographers. On female side, females grouped under others took the highest in number (Table 9).

Table 10: Annual effective doses of personnel exposure in medical diagnostics of 2004 in Addis Ababa, 2005. (n = 276)

Type of institution	**Mean(SD) shallow personnel Dose, mSv**	**Collective dose, man-Sv**
Government	0.422(0.321)	0.051
Private	0.401(0.195)	0.059
NGOs	0.322(0.002)	0.003
Total	0.407(0.255)	0.113

The mean (SD) of shallow dose of personnel of all institutions was 0.407 (0.225) mSv (Table 10).There was no a statistically significant difference among institutions (P value > 0.05). The mean (SD) of deep dose of personnel in government institutions was 0.285 (0.198) mSv and the mean (SD) of deep dose of personnel in private institutions was 0.267(0.178) mSv.

Quality control records

A completed radiation surveillance and quality control report form from January 2004 to February 2005 on diagnostic x-ray service of 78(92.9%) institutions from the total functional institutions (84) were collected from National Radiation Protection Authority.

Table 11: Type of institutions and machines collected from Regulator Department of National Radiation Protection Authority from January 2004- February 2005.

Variable	Frequency (n=78)	Percent
Type of institutions		
Private	58	74.4
Government	17	21.8
NGOS	3	3.8
Type of machines*		
Fixed	40	67.8
Combined	12	20.3
Mobile	7	11.9
Availability of local rule*		
Yes	51	65.4
No	24	30.8
Availability of warning sign		
Yes	66	84.6
No	12	15.4
Availability of warning label		
Yes	71	91.0
No	7	9.0
Control room has lead glass		
Yes	75	96.2
No	3	3.8

Note: * The total was not 78 due to missing data.

From 78 institutions, 58 (74.4%) were private and 17(21.8%) were government institutions .Regarding the diagnostic x-rays machines of these institutions, 40 (67.8%) were fixed and 12 (20.3%) were combined type (Table 11).

According to radiation surveillance and quality control records, the mean (SD) of patients load per week for diagnostic x-rays was 74.2 (65.3) patients. The mean (SD) patients examined for chest in the institutions was 6.22 (2.89) patients per day. The mean (SD) personnel working hours per week was 44.7 (9.58) hours. The wall material of 35(44.9%) institutions was brick. The mean (SD) thickness of the wall was 31.1 (8.3) cm. The mean (SD) area of the institutions was 27.3 (5.259) meter square. Eight (10.3%) areas of institutions were in unacceptable range. About 10 institutions had doors that were not leaded.

Table 12: Summary for quality control test of the diagnostic x-ray machines of institutions in Addis Ababa, January 2004-Feburary 2005.

Variable	**Acceptability**		**Total**
	Yes	**No**	
Voltage accuracy	63 (83%)	15 (19.2%)	78
X-ray timer accuracy	56 (71.8%)	13 (16.7%)	69*
Collimation and beam Alignment	60 (76.9%)	17 (21.8%)	77*
Output consistency	70 (89.7%)	7 (9.0%)	77*
Half value layer	75 (96.2%)	1 (1.3%)	76*
Leakage measurement	77 (98.7%)	1 (1.3%)	78

Note: *Tests were not done in some institutions due to different reasons.

According to the analysis of the National Radiation Protection Authority quality control records, 15(19.2%), 13(16.7%) and 17(21.8%) of institutions machines were deviated with in unacceptable range in their generator voltage, the machines timer and, their collimation and beam alignment respectively (Table 12). From 78 institutions, 65(83.3%) institutions work area doses were acceptable; where as, 11(14.1%) institutions work doses were not acceptable.

DISCUSSION

Unlike other studies, patients' dose received from examination of chest-PA, annual personnel dose report and quality control records of institutions were assessed. These provide the study a potential to identify the problems and indicate the possible solutions in diagnostic x-rays in Addis Ababa.

The result of this study indicated that the mean skin entrance dose per radiograph of patients examined for chest-PA was 1.88mSv.This was higher than the study conducted in Tikur Anbessa Referral Hospital Radiology Department on Skin Entrance Dose in hundred adult patients from routine P-A chest X-ray which was 1.24 mGy (22). These patients' doses are unacceptable with reference of the guidance level of international basic safety standards dose for diagnostic radiography for atypical adult patient entrance surface dose for chest-PA which is 0.4mGy; and the UK National Radiation Protection Board guideline dose for PA chest is 0.3mGy (8,11).

As this study showed that the mean entrance surface dose of patients from government institutions (2.45mSv) and patients from private institutions (1.58mSv); there was significant difference in entrance surface dose between government and private institutions (P value < 0.05).This might indicate the existence of difference in application of rules and regulation during supervision by National Radiation Protection Authority in government institutions and private institutions. This should be corrected by the Authority control and regulatory department.

Since for high-Kvp technique, the Kvp selected would generally be greater than 100 (4). All study institutions were used Kvp below 100. Thus, they have utilized low-Kvp technique for chest-PA examination. In multiple linear regression analysis, exposure setting (mAS) was on boarder level of significance (0.047). This might be due to the sample size for analysis was reduced to 169 from 215 patients' data for approximation of the data to normal distribution by selecting out extreme values during analysis. According to multiple linear regression analysis, every extra Kilovolt of a tube voltage increases deep dose for patient exposure by 0.009 and every extra mAS of exposure setting (i.e., the product of current and time) increases deep dose for patient by 0.003 (Table 7). Voltage was by far the major contributor to R^2 (multiple coefficient of determination).

A study conducted by Teshome Bayou on levels of doses to radiological workers in Ethiopia during the period 1977 to 1988 revealed that the annual average radiation dose exposure to the radiation workers monitored by TLDs was 4.51mSv.Besides the study in Sudan showed the average individual annual dose in different applications is less than 1mSv; and the study in Saudi Arabia demonstrates that the mean dose of diagnostic radiology personnel from 1998-2002 is in the range of 0.48-0.94mSv (18,20,23). Though, this study focused on radiological personnel of Addis Ababa, the annual mean shallow dose of personnel was 0.407mSv. Which is much less than Teshome's study but comparable to Sudan's study and Saudi Arabia's study. Teshome's study and Sudan's study included all radiation workers monitored by TLDs. In this study, only one personnel was above and another one personnel approached the dose limit of 20mSv per year recommended by IRCP (8).The collective dose of radiology personnel of this study was 0.113 man-Sv; but in Teshome's study the collective dose is 4.51 man-Sv (23).

As observed during data collection, most of the radiology personnel worked in addition to their normal working hours. This probably would increase their occupational radiation exposure. For such personnel monitoring, TLDs supply and result interpretation should be arranged to obtain their cumulative exposure so as to monitor them properly.

According to the National Radiation Protection Authority of Ethiopia unpublished report, from the total of 167 institutions covered nation wide, 41 of them (25%) required regular follow up and 10 of them (6%) were far below the acceptable standard (21). Although this study focused on Addis Ababa,11(14.1%) institutions work doses were not acceptable. 15(19.2%), 13(16.7%), and 17(21.8%) of institutions machines were deviated with in unacceptable range in their generator voltage, the machines timer and their collimation and beam alignment respectively. As result of strict confidentiality of the given data of National Radiation Protection Authority, triangulation this data with study institutions to see their patients' entrance dose was impossible. Since the radiation field should be adjusted to minimum size consistence with adequate clinical diagnosis by collimation. Voltage and current influence the intensity and strength of x-rays. Thus, malfunction of these quality parameters may have considerable amount of contribution to unnecessary exposure of patients and radiology personnel particularly, the radiographers of the institutions. Based on logistic regression analysis, patients that had exposure setting of x-rays for chest-PA greater than 25mAS were at risk for high dose than that of less than or equal to 25mAS [OR = 3.141; 95% CI = (1.170, 8.432)] (Table 6).

According to Linear-No-Threshold (LNT) theory, there is no safe dose of radiation and that regulations should establish exposure limits as low as possible if not zero (17). Thus, the national reference dose ought to be prepared and considered for patients doses for common radiological procedure like chest-PA.

LIMITATIONS

Since TLDs primary recommended for patients' doses measurement could not find from National Radiation Protection Authority of Ethiopia, Lithium Fluoride chips were used for measurement of patients' dose received from PA-chest x-ray which primary recommended for personnel dose monitoring. Basically, consultation of experienced professionals in the field and referring some studies which were used Lithium Fluoride chips of different types were referred before the progress of the study.

The existence of more than one dose reports for the same personnel were not cross checked with their names due to strict confidentially of the collected dose data of the National Radiation Protection Authority.

CONCLUSION

Entrance dose assessment of patients examined for chest –PA was done in 43 health institutions existing in Addis Ababa where better health services were expected; but majorities of the patients' received doses were found in unacceptable range. Thus, great efforts have been needed to minimize the medical radiation exposure of patients examined for chest-PA to low level as much as reasonably achievable.

Annual mean dose of monitored radiology personnel in Addis Ababa was found low compared with other similar studies; but this should coincide with some factors which determine the dose like proper TLDs wearing position and always wearing the TLDs in working time which were not considered in this study.

RECOMMENDATIONS

Taking in to consideration the study results, the following are recommended:

- The National Radiation Protection Authority should strength its effort in controlling diagnostic x-rays units equally in different types of institutions and providing refreshment courses for radiology personnel in order to reduce medical exposure of patients examined for chest-PA with out compromising the diagnostic value and facilitate means of increasing public awareness so as to improve their attention during medical exposure of x-rays.

- Since Ionizing radiation exposure has a cumulative effect, radiology personnel working in different institutions as part-timer should have one reference number for their TLDs dose reports which are analyzed for their different TLDs in the personnel dosimeter laboratory to assess their cumulative dose.

- A similar study ought to be initiated in regions to examine the magnitude of the problems in radiation exposure of diagnostic radiology.

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ANNEX-I

English Version Questionnaire
Addis Ababa University
Faculty of Medicine
Department of Community Health

- Questionnaire for Assessment of Radiation Exposure of Diagnostic X-rays in Addis Ababa.
- Questionnaire Identification number____________
- Name of the institution_________________________________

Verbal consent form

Greeting: Good morning / good afternoon. My name is _____________.I am working in the research team of Addis Ababa University of Medical Faculty of Community Health Department. I would like to ask you a few questions about you. The purpose of this study is to evaluate radiation exposure of diagnostic x-rays. The information collected about you will be treated in a confidential manner and that you will not personally identified in the reporting of the results. Your participation is entirely voluntary and that you may refuse to answer any questions if you choose, or may withdraw your consent to participate. May I continue to the questions?

1-If yes, continue to the next page.

2-If no, describe the reason briefly____

____and skip to the next participant.

Interviewer code___________name ________________ signature_________

Date of interview__________ Time started_________

Time completed__________

Result of interview-1-completed -2-Partially completed
-3-respondent not available -4-refused

Supervisor name___________signature_________date____________

DATA REQUEST FORM FOR PATIENTS
A-measurement of entrance surface dose per radiograph

Sr.no	List of questions	Choices to be circled/ answers to be written according to the question	Skip pattern	Coding column
	GENERAL INFORMATION			
100	Name of the institution			
101	Type of institution	1-government 2-private 3-NGOs		
	PATIENT DATA			
102	Sex	1-male 2-female		
103	Age	___________year		
104	Weight	___________Kg		
105	Height	___________cm		
106	Do you have previous x-ray exposure?	1-yes 2-no	If no, skip to 108	
107	How many times?			
	EXAMINATION DATA			
108	Type of examination			
	RADIOGRAPH DATA			
109	TLD code number			
110	Film focus distance(FFD)			
111	Type of film			
112	Type of screen			
113	Tube voltage	___________Kv		
114	Exposure setting	___________mAS	If no, Skip to 116	
115	Millampere	__________mA		
116	Exposure time	__________Second		
	EQUIPMENT DATA			
117	Type of x-ray machine	1-fixed 2-mobile		
118	Model			
119	Tube serial number			
120	Manufacturer data			
121	Year of the x-ray machine in this institution			
122	How many times the x-ray Machine maintained last year?			

Thank you!!