

**Occupation Radiation Exposure on Radiographers
and Radiologists: Levels and Risks at University
Teaching Hospital and Cancer Disease Hospital,
Lusaka Zambia**

By

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DEDICATION

I dedicate this work to my family, friends and the Public Health team at the University of Zambia

Abstract

Background: Radiation exposure and its potential complications is one of the most important issues in occupational health. Implementation of proper occupational health system may have an important bearing not only on the health of the population occupationally exposed to radiation but also on the health and prosperity of the community. The study aimed at analysing the radiation dose received by workers and assessing their perceptions about their exposure.

Methods: The study used embedded mixed methods design. Doses for Radiographers, Radiologists, Medical Physicists and Nurses working at Cancer Disease Hospital (CDH) and University Teaching Hospital (UTH) were analysed. Thermoluminescent dosimeters (TLD) were used to review radiation doses over a 3-year period (2013-2015). Random effect linear regression model was used to identify potential risk factors of radiation dose. Key informant interviews and semi structured questionnaire were conducted at both sites.

Outcomes: There were 55 records from UTH and 43 from CDH for the quantitative part. For the qualitative part, there were 16 respondents 14 from UTH and 2 key informants from CDH and UTH. About 5.3% of the radiation doses were above the 1.2mSv lower monthly monitoring level. Being female (p-value 0.035) and being at UTH (p-value 0.041) was associated with higher radiation dose. UTH had a mean dose of 0.69 mSv, SD 0.9 (95% CI =0.47- 0.78) and this was higher than CDH which had mean dose of 0.46mSv, SD 0.3 (95% CI= 0.25 -0.364) over the period under review. When the dose exposure was stratified according to sex, women had a higher mean dose of 0.46 mSv (SD 0.3) than Men who had 0.69 mSv (SD 0.4 P-value=0.012.)

Majority of the workers thought that they were being overexposed to radiation. They cited a number of factors that they thought were contributing to these levels including, state of equipment, and human factors.

Discussion/Conclusion: Occupation radiation exposure at UTH and CDH were found to be within monitoring limits. However about 5.3% of radiation doses were above the 1.2 mSv lower monthly monitoring level. There is need for continued education and training of personnel in principles of radiological protection as well as strengthening the monitoring system.

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List of Abbreviations

ALARA: As Low As Reasonably Achievable

BEIR: Biological Effects of Ionizing Radiation

CDH: Cancer Disease Hospital

CT: Computed Tomography

ERR: Excess Relative Risk

IAEA: International Atomic Energy Agency

ICRP: International Commission on Radiological Protection

LET: Low Linear Energy Transfer

LNT: Linear Non-Threshold

mSv: millisievert

NCRP: National Council on Radiation Protection and Measurements

RR: Relative Risk

SMR: Standardized Mortality Ratio

UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation

UTH: University Teaching Hospital

WHO: World Health Organisation

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CHAPTER 1 INTRODUCTION

1.0 Background of the study

From the earliest days of experimenting with radiation it became known there were levels of exposure at which injury to human tissues could occur, such that occupational radiation exposure needed to be controlled for the safety of radiation workers. In 1896 the first injuries due to x-ray exposure were recorded and in 1904 Thomas Edison's assistant Clarence Dally was the first person recorded to have died as a result of x-ray exposure (Abel R. et al, 2006).

The scientific discovery of radiation has been further developed and now being used in radiology. Radiology is a medical speciality that uses imaging to diagnose and treat disease seen within the body. Radiologists use a variety of imaging techniques such as X-rays radiography, ultrasound, Computed Tomography (CT), Positron Emission Tomography (PET), and Magnetic Resonance (MRI) to diagnose or treat diseases (Health physics society, 2013).

The use of radiology has overall societal benefit, but the high radiation doses involved with therapeutic exposures have the potential to cause harm to those who benefit from the treatment and to health care staff and members of the public if inadvertent radiation exposure occurs (Australian Radiation Protection and Nuclear safety Agency, 2008).

Africa is sharing the benefits of advances in medical imaging technology that makes it possible for doctors to more quickly diagnose and treat serious illnesses. However, the stunning new machines have brought along some problems of unknown magnitude in the absence of adequate monitoring of staff for radiation exposure (Sasha H. 2009).

1.1 Importance of Nuclear Technology in Medicine

Ionizing radiation serves three important purposes in medicine. First, it makes it possible for physicians to diagnose many conditions that would be difficult or impossible to diagnose in any other way. The most well-known use of radiation in medicine is the creation of images of the inside the human body. Images can be

formed in two general ways by directing x rays through the patient's body (diagnostic radiology) or by administering radioactive pharmaceuticals to the patient (Health physics society, 2013).

Second, ionizing radiation is also used to treat cancer by directing intense beams of x rays, gamma rays, or protons directly at the area of the body where the tumour is located. These intense beams are usually produced by large electronic machines called accelerators or cyclotrons, but in some cases a radioactive source is implanted in the tumour either for a short time or permanently. Finally, small amounts of radioactive materials are used in the laboratory to analyse blood and tissue samples or to conduct research (Health physics society, 2013).

1.2 Epidemiological Studies of Radiation Exposures

The Life Span Study (LSS) cohort of survivors of the atomic bombings in Hiroshima and Nagasaki continues to serve as a major source of information for evaluating health risks from exposure to ionizing radiation, particularly for developing quantitative estimates of risk. This is because it has large size, the inclusion of both sexes and all ages, a wide range of doses that have been estimated for individual subjects, and high-quality mortality and cancer incidence data. In addition, the whole-body exposure received by this cohort offers the opportunity to assess risks for cancers of a large number of specific sites and to evaluate the comparability of site-specific risks. As such many studies that have been conducted relating to risk estimates of radiation have utilised this information or indeed results from studies borrowing this data (National Research Council, 2006).

A survey of the health of radiologic technologists (143,000 Radiologists) (Boice and others 1992) gathered information on risk factors including smoking status, reproductive history, use of oral contraceptives, personal exposure to radiographs, height, weight, use of hair dye, and postmenopausal estrogens, and family and personal medical history of cancer. Members of the study population (n = 143,517, registered for more than 2 years with the American Registry of Radiologic Technologists, ARRT) were predominantly female and white. Nearly 4% of respondents reported having some type of cancer, mainly of the skin (1517), breast (665) and cervix (726). The study observed correlation between occupational

exposure and personal exposure to medical radiographs, related in part to both factors with attained age.

In another cohort study using the American Registry of Radiologic Technology (AART) database (Doody and others 1998) reported Standard Mortality Ratios and Relative Risks adjusted for age, calendar year of follow-up, and gender. No significant excess mortality among radiological technologists was observed for lung cancer, breast cancer, or leukaemia. The Standardized Mortality Ratio (SMR) for all malignant neoplasms exhibited a significant trend with the number of years certified ($p < .001$), as it did for breast cancer. The study also observed that in the absence of complete personal dosimetry information, accurate estimates of risk due to exposures to ionizing radiation are not possible.

Yoshinaga and colleagues (1999) reported results from a retrospective cohort study of radiological technologists in Japan. This study made external comparisons with all workers and with professional and technical workers to address the issue of the healthy worker effect. The study used all Japanese men as the external comparison group; the SMR for all cancers in this study was 0.81 (95% CI 0.73, 0.95). Although elevated SMRs were observed for cancers of the colon, skin, lymphoma, multiple myeloma, and leukemia, none was statistically significant. The SMR for leukemia was significant in comparison to the total workforce as the reference group (SMR = 1.99; 95% CI 1.09, 3.33) and also for professional and technical workers as the reference group (SMR = 1.82; 95% CI 1.00, 3.06).

The above studies suggest that there is evidence to believe that low radiation exposures can be associated to health effects. Some Standard Mortality Ratios obtained in these studies indicate an increased mortality in radiographers as compared to other health workers and general population respectively.

The established model for determining carcinogenic effects at low doses in radiation protection is based on the hypothesis that the cancer incidence increases proportionally with radiation dose. A so called linear no threshold model has been adopted by most national and international bodies. The major implication of the no threshold model for stochastic effects is that all doses, regardless of how low they are, must be considered potential carcinogenic but that some risk must be accepted at any level of protection (UNSCEAR, 2000).

1.3 Radiation Protection Standards

Radiation protection is concerned with protecting people from the harmful effects of ionizing radiation while allowing its beneficial use in medicine, science, and industry. Radiation protection standards and the philosophy governing those standards have evolved in somewhat discrete intervals. The changes have been driven by two factors, new information on the effects of radiation on biological systems and changing attitudes toward acceptable risk. The earliest limits were based on preventing the onset of obvious effects such as skin ulcerations that appeared after intense exposure to radiation fields. Later limits were based on preventing delayed effects, such as cancer, that had been observed in populations of people receiving high doses, particularly from medical exposures and from the atomic bomb exposures in Hiroshima and Nagasaki (Health physics society, 2013).

On an international level, the International Atomic Energy Agency (IAEA) develops nuclear safety standards, promotes the achievement and maintenance of high level of safety in applications of nuclear energy, and protects human health and the environment against ionizing radiation (International Atomic Energy Agency, 2012). Despite the regulations implemented, cases of occupational radiation still persist. Some studies indicate that non-compliance with radiation safety may be directly attributed to the lack of knowledge and proper training for employees of the company. Other references stress the lack of skill in radiation protection in certain hospitals as the primary reason for the non-compliance (Friberg EG, AW, 2011, Anita Marie Slechta MR, 2008)

In Zambia radiation exposure is guided by the Ionising Radiation Protection (Amendment) Act Cap 311, of 2011, as read with the Ionising Radiation Protection Act, of 2005. The radiation safety requirements prescribed under this Act do not extend to patients undergoing medical treatment by exposure to radiation by or under the supervision of a medical practitioner; but do apply to the safety of medical and technical staff working with the radioactive material or source of dangerous ionising radiation and to the protection of all other persons, other than the patient undergoing treatment.

Subject to such exceptions as may be contained in any regulations or licence issued under this Act, the standard of radiation protection to be met for the purposes of this Act shall be the maximum permissible levels of radiation established and accepted internationally and published from time to time by the International Commission on Radiological Protection (Ionising Radiation Act, Cap 311).

The following table gives some of potential health effects and dose limits.

Table 1 : Radiation doses, dose limits and potential health effects

Dose	Limit or Health Effect
More than 5,000 mSv	Dose that may lead to death when received all at once
1,000 mSv	Dose that may cause symptoms of radiation sickness (symptoms include tiredness and nausea) if received within 24 hours
100 mSv	Lowest acute dose known to cause cancer
30–100 mSv	Radiation dose from a full-body computed axial tomography (CAT) scan
50 mSv	Annual radiation dose limit for nuclear energy workers
1.8 mSv	Average annual Canadian natural background dose
1 mSv	Annual public radiation dose limit in Canada
0.1–0.12 mSv	Dose from lung X-ray
0.01 mSv	Dose from dental X-ray
0.01 mSv	Average annual dose due to air travel

(Canadian nuclear safety commission, 2012)

1.4 Radiation exposure incidences and health risks.

Health effects from exposure to radiation range from no effect at all to death, including diseases such as leukemia or bone, breast, and lung cancer. Very high (100s of rads), short-term doses of radiation have been known to cause prompt (or

early) effects, such as vomiting and diarrhoea, skin burns, cataracts, and even death. (National Research Council, 2006)

The finding by Pierce and others (1996) showed a statistically significant trend in the Life Span Studies (LSS) mortality risks over the range 0-0.05 Sv for all solid cancers. The results indicate that for survivors with doses of 0.02-0.05 Sv, observed cancer rates were increased by 5%, compared with predicted value of 2% based on a linear model fitted over a wider range of doses. This shows that there could be a deviation to the linearity model.

CHAPTER 2 OBJECTIVE

2.1 Research Questions

- What are the existing levels and risks of occupation radiation exposure at UTH and CDH?
- What factors are contributing to the existing levels of exposure?

2.2 General Objective

To determine the radiation levels, associated risks, and adherence to safety guidelines among Radiographers and radiologists at University Teaching Hospital and at Cancer Disease Hospital, in Lusaka, Zambia.

Specific Objective

1. To establish existing levels of radiation exposure among Radiologist and Radiographers
2. To identify factors that contribute to existing levels of exposure
3. To asses perception of radiation safety standards and possible effects of radiation among radiologists

2.3 Statement of the Problem

The number of workers affected by occupational radiation exposure is increasing, particularly in radiation medicine. About 7 million health workers receive radiation doses attributable to their occupation each year around the world. Occupational exposure for health workers is high in some instances and could result in serious consequences if appropriate radiation protection measures are not implemented (WHO, 2008)

The hospital industry is one of the industries with a number of different occupational hazards. This is why individuals in the industry have good compensation and adequate protection. On top of the list for high level of protection is the field of medical radiation (Carpio MA, Yap M 2014). Cases of nonfatal occupational injuries and illnesses among health care workers are some of the highest in any industry sector (NIOSH, 2012).

It is apparent that health workers who are involved in Radiology are likely to be exposed to protracted Dose levels of radiation above the normal or background dose. There is a challenge however in establishing the actual Health effects resulting from low doses exposures. This is due to the fact that human beings are exposed to low level radiation from the environment thus it becomes difficult to distinguish occupational exposure effects from those resulting from natural or environmental radiation. Much more also, low dose radiation levels are difficult to quantify in terms of their effects because they do not cause immediate effects.

Effects of occupational exposure to radiation have been documented for long now. For example Dublin and Spiegelman (1948) in their study on the effects of radiation observed that there was increased mortality from leukemia among radiologists compared to mortality among other medical specialists.

Radiotherapy has become a standard treatment option for a wide range of malignancies. The U.S. Surveillance, Epidemiology, and End Results data show that radiation is commonly included in primary oncologic interventions. Between 1991 and 1996, for example, radiotherapy was used in the initial management of 32.9% of prostate cancers and of 44.1% of lung cancers in the United States. When subsequent

palliative interventions are also considered, more than half of cancer patients require radiotherapy during at least one point in their care (Phillip P. etal, 2009).

It is estimated that, currently, approximately 70% of cases in Zambian hospitals are referred to radiology at some stage of case management (Tropical Health and Education Trust United Kingdom and Ministry of Health, 2007). This indicates how relevant radiology is in medical practice; as such there is burden of case management by radiologists.

Both UTH and CDH are faced with a challenge of skilled human resource to manage radiological equipment. Though significant progress has been achieved in the development of medical imaging in Zambia, There is no clear policy and whether current standard operating procedures are adequate followed. Furthermore, there is lack of educational facilities for advancement in education, coupled with poor public awareness on hazards of radiation. This puts the medical workers involved at risk

2.4 Justification

Radiation occupational exposures to radiographers are eminent and the risks significant. The linear no threshold model emphasises the risk even at low dose radiation (National Research Council, 2006). Therefore was imperative to analyse exposure levels in order to estimate the risks posed to radiographers and radiologists. This will give a picture of the extent of the problem and facilitate improvements hence making radiography a lifesaving and less risk profession.

This study also analysed the enforcement of regulations that govern radiation protection in Zambia. The study identified gap in enforcement of regulations and made recommendations to ensure that radiation exposed workers are adequately protected. In this regard, the study will be useful to provide additional information to policy makers that can lead to improvement in the protection of health care workers in medical radiation industry.

CHAPTER 3 METHODOLOGY

3.0 Study Setting

The study was conducted at The University Teaching Hospital (UTH) and Cancer Disease Hospital. UTH is the largest hospital and main referral hospital in Zambia, located in the capital city Lusaka about 4Km east of the city centre. UTH is the principle medical training institution in the country. It has approximately 1655 beds and 250 baby cots. It provides a full range of primary secondary, and tertiary health and medical services on both inpatient and outpatient basis. Radiology Department is among the 11 departments in the Hospital. The others include: Anaesthesia, Internal Medicine, Obstetrics and Gynaecology, Paediatrics, Department of Surgery, Community medicine, Internal Medicine, Radiology, Physiotherapy, Pharmacy and Bland bank.

Cancer Disease Hospital is a specialised institution located within the premises of UTH. It is an ultramodern facility that uses state of the art equipment to provide radiological and palliative care of cancer patients. It was opened in 2007 and receives cancer patients from all parts of the country.

3.1 Study Population

The study population comprised of all radiographers and radiologists at the University Teaching Hospital and Cancer Disease Hospital.

3.2 Study Design

The study employed embedded mixed methods. The main reason for using mixed methods was to seek complementarity and clarification of the results from quantitative method with the results from the qualitative methods (Greene, Caracelli, and Graham, 1989). The two components of the study were combined during the discussion of the findings. The qualitative results helped describe some of the quantitative results, as well as answer some research questions.

3.3 List of Variables

	Variable	Type of variable	Indicator	Scale of Measurement
Response	Radiation dose	Continuous	High radiation exposure levels	Sieverts (Sv)
Explanatory	Maintenance of equipment	Continuous	Frequency of maintenance	Number of times per year
	Training	Dichotomous	Radiation safety training	Present Absent
	Radiation shielding	Dichotomous	Presence of radiation shielding mechanism	Present Absent
	Age	Continuous	Number of years	Years
	Sex	Dichotomous	Ratio of men and women	Male Female
	Hospital	Dichotomous	Wilful Violation of procedure	0 (UTH) 1 (CDH)
	Acquired Age	Continuous	Number of months in radiology environment	Months
	Regulatory control	Dichotomous	Insufficient regulatory control	Compliant Non-compliant

3.4 Sampling Methods

Non-probability convenient sampling method was used to select UTH and CDH. This was because it is the biggest Hospital in Zambia so expected to have the biggest number of radiographers and radiologists as this would add more power to the study. Workers to be interviewed were selected by random sampling. The sampling frame was stratified according to the hospitals (UTH and CDH).

3.5 Quantitative

The quantitative method involved retrospective analysis of already collected radiation exposure records (secondary data). Worker record files were used to provide exposure levels during the period under review (2013-2015) and these records were analysed. All the workers who were being monitored during this period were included in the analysis. This constituted the main (primary) component of the study.

3.5.1 Data Collection

Data for worker's exposure was obtained from occupation radiation exposure dose files from Radiology department which are compiled by the Radiation Protection Officers (RPO).

Inclusion Criteria

- All Radiographers, Radiologists, Nurses and Medical Physicists.

Exclusion Criteria:

- Radiographers, Radiologists, Nurses and Medical Physicist without records during the period under review (2013-2015)

3.5.2 Data Collection Techniques and Tools

Data from worker exposure files was be analysed. We used data extraction check list used to get information about exposure levels from workers record files. The variables of interest were: Sex, exposure dose, hospital, and type of training received.

3.5.3 Plan for Data processing and Analysis

Quantitative data was analysed using STATA version 13.0 (Stata cop, college station, Texas, USA). First we assessed normality of the data by using quantile, quantile plots (qq). For each variable, the following summary statistics were reported:

- **Continuous data** (exposure dose), mean and standard deviation
- **Categorical data** (Sex, work place), proportions

In order to assess association of radiation dose and hospital (UTH and CDH) a two sample t-test was used.

Given that the data had repeated measures, it was declared as panel data in stata before running any analysis. Random effect linear regression model was used to identify potential risk factors of mean radiation levels. This was arrived at after running Hausman specification test (Hausman, 1978) for model suitability after failing to reject the null hypothesis that the individual effects were uncorrelated with the other regressors. Breusch and Pagan Lagrangian multiplier test for random effects at the p-value was <0.001 was run to decide between random effects regression and a simple Ordinary Least Square regression.

3.5.4 Data Integration: The data from the two components was collected, and analysed separately, it was thereafter integrated when discussing the findings.

3.6 Qualitative

The qualitative component was a cross section survey. This part of the study helped better understand factors that could contribute to the existing levels of exposure.

3.6.1 Data Collection

We used a semi structured questionnaire and key informant interviews to collect our data for this part of the study. Semi-structured interviews were administered to radiographers and radiologist at Cancer Disease Hospital and University Teaching Hospital. We also selected two key informants from each of the two Hospitals and Radiation Protection Authority.

3.6.2 Data Processing and Analysis

For written responses, thematic analysis was done. This was by generating emergent themes using Steps Coding and Theorization. This method is applicable for analyses of open-ended questionnaire responses. The written responses were first be reviewed by the researcher and significant categories were extracted. These were then coded by content, keeping the original opinion intact. The qualitative design adhered to Relevance, Appropriate, Transparency, and Soundness of interpretation (RATS)

3.7 Ethical Considerations

The following are some of the ethical issues that were considered in the study:

Secondary data poses a number of ethical issues. Most importantly, the workers did not consent to have their radiation exposure levels analysed in a study such as this one. Also linking exposure levels and possible health effects to workers may cause stigmatisation to such workers. In consideration to ethical principles, the researcher de- identified all records so that exposure levels were anonymous. Our justification for going ahead and analyse the dose was that the results of this study may have a benefit to a greater number of people in the medical field and society in general.

For the qualitative aspect of the study, before any interviews, the purpose of the study was explained to the respondents, and informed consent was sought. A few personal questions were asked pertaining number of children the workers had while working in radiological environment. The personal questions were aimed at assessing whether workers may be able to relate exposure to any medical conditions that their children have. This information was treated with outer most confidentiality. We also informed the respondents about their right to either decline or participate in the study or withdraw at any point in the interview. There were very low risks to the participants because only their perceptions on the levels of exposure were assed. This did not raise much anxiety because the workers interviewed have all been in formal training and they have the basic understanding of radiation. As such asking them about radiation exposure did not seem to cause much anxiety.

Prior to the commencement of the study, approval of this study was obtained from the ethics committee of the University Of Zambia, School Of Medicine (University

of Zambia Biomedical Research Ethics Committee) Reference number **002-07-15**. Approval was also sought from the Hospital Management before the commencement of the study. All the information on exposure obtained was treated with utter most confidentiality.

CHAPTER 4 QUANTITATIVE RESULTS

4.0 Overall Population Description

Table 2 Distribution of selected demographic factors of the study population

Survey N=30 ^a		
	Proportion from CDH	Proportion from UTH
Sex		
Male	56.25 % (9/16)	57.14% (8/14)
Female	43.75% (7/16)	42.85 % (6/14)
Age		
20 – 25	31.25% (5/16)	21.42% (3/14)
25-30	43.75% (7/16)	21.42% (3/14)
30-35	12.50% (2/16)	14.28% (2/14)
35-40	12.50% (2/16)	14.28% (2/14)
40-45	0	28.57% (4/14)
Mean	29 (5 Sd)	34(9 Sd)
Marital Status		
Married	37.50 % (6/16)	50% (7/14)
Single	62.50 % (10/16)	50% (7/14)
Number of Children		
0	68.75% (11/16)	43% (6/14)
1	12.50% (2/16)	7% (1/14)
2	0% (0/16)	29%(4/14)
3	18.75% (3/14)	7%(1/14)
4	0% (0/14)	14% (2/14)
Secondary Data^b		
	N=55	N=43
Male	52.73 % (29/55)	46.51% (20 /43)
Female	47.27 % (26/55)	53.49 % (23/43)
Occupation		
Radiologist	2% (1/55)	14% (6/43)
Radiographer	93%(51/55)	65% (28/43)
Nurse	3% (2/55)	12% (5/43)
Medical Physicist	2% (1/55)	9% (4/43)

^a Primary data collected from the survey, ^b Secondary data collected from worker's files

4.1 Social Demographic Characteristics of Study Participants

The survey had 30 participants of which 47% (N=16) were from cancer Disease Hospital and 53% (N=14) were from University Teaching Hospital. The median age for CDH was 27.5 ± 5 and for UTH was 32 ± 9 . From both hospitals, 13 (43%) were female and 17 (57%) were male. 13 participants reported that they had children during the period they worked in radiation environment while 17 reported zero number of children for that period.

The age profile of respondents in this study reveals that that majority of the respondents were aged 25-30 represented by n=10 and 70% of this proportion (N=7) was from CDH, followed by age groups 20-25 represented by n=4 (28.57%) and this is the proportion from UTH.

With respect to respondents' marital status, it was observed a higher proportion of members n=10 (60.5%) were single from CDH while there was an equal number were either married or single n=7 (50%) from UTH respectively.

For the secondary data from CDH and UTH, 49 were male and 49 were female. 81% were Radiographers 7% were Radiologists, 7% were Nurses and 5% were Medical Physicists.

4.2. Radiation Dose

The table below shows the average radiation dose received stratified by hospital, sex and occupation.

Table 3 Average radiation dose received

	Dose (mSv) /SD*	p-value
CDH	0.46 (0.3)	
UTH	0.69 (0.9)	0.0002
Male	0.46 (0.3)	
Female	0.69 (0.4)	0.012
Medical Physicist	0.42 (0.2)	0.563
Nurse	0.44 (0.2)	
Radiographer	0.67 (0.9)	
Radiologist	0.38 (0.3)	

SD* standard deviation, Note that about 5.3% records were above the monthly monitoring dose of 1.2mSv

With regard to radiation dose, the mean dose was 0.58mSv (0.72 SD). When stratified according to hospital, UTH had mean 0.69mSv, 0.9 SD and CDH had mean 0.46 mSv, 0.3 SD (95% CI= 0.25 -0.364), Medical Physicists had mean dose of 0.42 mSv 0.2SD, Nurses had 0.44 0.2SD, Radiographers 0.67 mSv 0.9 SD and Radiologists 0.38 mSv 0.3SD

We run a two sample t-test in order to assess the difference in radiation dose received at UTH and CDH. Figure 1 shows the differences and the P-value for this test.

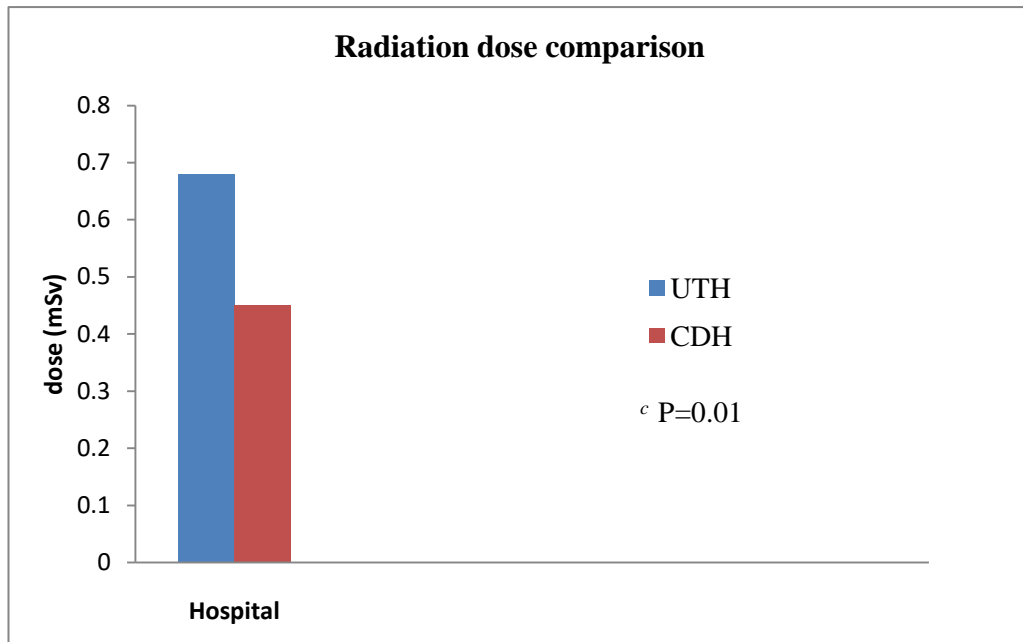


Figure 1: Comparison of radiation dose at UTH and CDH

The histogram above shows comparison of the mean radiation dose received by UTH and CDH.

^c Two sample t-test for unequal variance showed that there was a statistically significant difference in the mean radiation score between UTH and CDH

4.3 Regression Analysis for possible predictor of high radiation dose

A univariate analysis of possible predictors of high radiation dose was run; thereafter run a multivariate model for those variables which were significant at P-Value of 0.1 in the univariate. Table 4 and 5 show the output of the univariate and multivariate models respectively.

Table 3 univariant regression analysis possible predictor of high radiation dose

	Coefficient	95% CI	P-value
Sex (male) ^a	-0.21	-0.42-0.01	0.058
Hospital(CDH) ^b	-0.31	- 0.43- -0.001	0.045
Radiologist	-0.03	-0.60- 0.52	0.89
Radiographer	0.23	-0.29- 0.77	0.38
Nurse	0.02	-0.66- 0.69	0.97
Medical physicist ^c			

^aFemales were the reference point in the bivariate regression of the variable sex. ^b

UTH was the reference point for the variable Hospital ^c Medical physicist was the reference point in the univariant regression of the variable occupation.

Table 4: Multivariate Analysis of the predictors of radiation dose

	Coefficient	95% CI	P-value
Hospital (CDH)	-0.21	-0.414- -0.01	0.041
UTH*	Null	Null	Null
Sex (Male)	-0.21	-0.4174512 -0.01	0.035
Female*	Null	Null	Null

*UTH was the reference in the analysis, Female was the reference in the variable sex

4.4 Cancer risk calculation.

The study estimated the lifetime risk of cancer associated with an occupational radiation exposure of 0.6mSv, as well as with the annual dose limit (20 mSv) as established in the Ionising Radiation Protection cap 311 of the Laws of Zambia. Table 6 shows the estimated risk of cancer calculations.

Table 5 Risk of cancer when exposed to 0.6mSv and annual exposure limit of 20 mSv

Exposure	Lifetime risk ^a	Average annual risk ^b
Average dose over period in review (2013-2015): 0.6* mSv/a	8.4×10^{-4}	1.6×10^{-5}
Annual monitoring dose limit: 20 mSv/a	2.8×10^{-2}	5.4×10^{-4}

* rounded value for 0.58mSv (The average radiation dose during the period of monitoring)

* Nominal probability coefficient for stochastic effects in an adult worker was 4.0×10^{-2} per sievert according to the ICRP Publication 103.

^a This lifetime risk is obtained by multiplying the level of annual exposure by 35 years and by the fatal cancer risk coefficient ($4.0 \times 10^{-2}/\text{Sv}$). The coefficient is according to the recommendation of the ICRP publication 103. The 35 years is an estimated number of years someone may work in radiation environment, having started work at the age of 20.

^b In order to obtain the average annual risk, the lifetime risk is divided by the lifetime expectancy of individuals. In the case being considered, i.e. that of occupational exposure, it has been assumed that the exposure will start at 23 years old.

CHAPTER 5 QUALITATIVE RESULTS

For this part of the study, semi structured questionnaires were administered, also conducted key informant interviews. These were stratified according to working place. There were 16 respondents from UTH, 14 respondents from CDH and 2 Key informants from UTH, CDH and Radiation protection Authority respectively.

5.1 I. Perceived doses and effects of radiation exposure

Perception of the amount radiation dose a worker is exposed and possible health effects is thought to influence their safety consciousness. If a worker thinks they are not exposed to high amount of radiation dose, they are unlikely to be prudent in following protective measures such as shielding, distance and time.

For UTH and CDH, when radiation monitoring is done the TLD readings are availed to the workers via their respective departments. This feedback mechanism where the worker is availed with the monthly dose reading is important so that the worker can improve on their safety precautions. The respondents indicated that they relied on these readings to know whether they were being over exposed or not. Thus the TLD readings influenced their perception of the amount of radiation they were exposed to. However, some of the workers stated that they did not have radiation monitoring badges (TLD) and that they usually didn't get feedback. Regarding the respondents' perception of the amount of radiation they were being exposed to, the majority perceived that they were being overexposed. The following comment from respondent is an example that illustrate this point,

I'm over-exposed to radiation this is mainly due to monitoring inconsistencies with the radiation authority board and improper maintenance of equipment (Respondent 4, UTH)

...from theater I am exposed above acceptable limits for pacemaker exams (Respondent 13, UTH)

The study also assessed respondents' knowledge on the possible health effects that could result from occupational radiation exposure or as to whether they could relate

any health problems that their children may have had. When asked about whether they knew any diseases or condition that may be due to radiation exposure, the majority of participants reported cancers, gene mutation, infertility stochastic and non-stochastic effects were also reported. Of the 29 participants, the majority reported that they had no children with conditions that they could relate to radiation exposure (n = 27, 93%). The minority reported having children with adenoid hypertrophy (n = 2, 7%).

Problems due to radiation exposure may include stochastic effects and non stochastic effects may also be seen in my future offspring (Respondent 21, UTH).

Risk of cancer in women -breast cancer, risk of disabilities to the offspring due parental exposure to radiation and leukemia (Respondent number 7 CDH)

5.2 Factors Associated with Exposure

Workers have perceived factors that could lead to radiation overexposure and generally the existing levels of radiation dose at the two hospitals (UTH and CDH). The respondents cited a number of factors that could lead to overexposure. There were a lot of issues that were raised. These included long working hours, incompetence of the workers, lack of adequate knowledge about radiation safety, accidental irradiation and non adherence to work rules. These factors were seen to be mainly belong in the following categories: poor safety measures, faulty equipment and radiation facilities,

a) Safety Measures

More than half of the participants perceived safety measures as a factor leading to existing levels of radiation exposure in their work environment. This perception was two-fold with the majority perceiving that there were inadequate safety measures in place while the rest perceived otherwise. Emerging themes included lack of radiation leakage survey and inconsistencies in radiation monitoring. A few participants reported adherence to radiation safety regulations, conduct and practice.

There is poor application of radiation safety measures and lack of monitoring of radiation doses through Radiation Protection Authority. (Respondent 2, UTH)

Poor application of radiation protection measures by radiology staff and other staff who know less about radiation protection. (Respondent 24, CDH)

b) Equipment

The status of the equipment used was cited to be another contributing factor to the existing levels of exposure. There were reports of inconsistencies in equipment maintenance which lead to use of malfunctioning equipment consequently causing radiation leakage. Respondents also highlighted that they have limited protective accessories such as lead aprons for protection and that there were cases of leaking rubber aprons.

There is inconsistency in equipment maintenance, lack of regular monitoring by RPA, lack of regular equipment quality control tests. (Respondent number 7, UTH)

The existing poor status of the machines e.g in one of the imaging rooms, the collimators don't work as such there is no proper collimation. (Respondent 21, CDH)

c) Radiation Facilities and human factors

The status of the radiation facilities was perceived to play a role in the existing levels of radiation exposure. The common themes raised were radiation leakage and ventilation.

Radiation leaking door in a radiograph department (Respondent 27, UTH)

There also human factors that were attributed to overexposure. The respondents cited accidental exposure, negligence and carelessness, non adherence to work rules and incompetence of the worker. Poor work practice and ignorance was also mentioned.

Non-observance of radiation safety practices. These are time, distance and shielding (Respondent 9, CDH).

There were situations where a worker would leave the badge in a room where it is exposed to radiation for a long time. In some instances workers would deliberately expose the badges so that they get leave day (KI.)

5.3 Radiation Guidelines

Operations of radiation facilities in Zambia are guided by the Ionising Radiation Protection (Amendment) Act, 2011, read as one with the Ionising Radiation Protection Act, 2005. The Act gives guideline on licensing, acceptable limits and how the facilities are to operate,

The majority of participants reported that guidelines were not adequately followed while some reported that guidelines were adequately followed. However none of the respondents knew the annual exposure limit. It was clear from the responses that most of the workers didn't understand the guidelines. Workers in radiation environments are supposed to wear TLD badges. When asked what is done to workers who do not follow the guidelines such as time, distance, and shielding as well as wearing of badges, some respondents said they are reprimanded and also educated on the dangers of ionizing radiation. The majority however reported that a number of workers do not wear and nothing is done to them. There were suggestions that there was poor enforcement of the regulations.

Honestly speaking the guidelines are not adequately followed. My reason for this answer is that most of the imaging procedures are usually manipulated due to poor status of the machines. There is a diversion from standard guidelines (Respondent 12, UTH)

We tried to establish the actions taken when a worker is reported to have been overexposed to radiation. The common theme raised included radiation leave. Some respondents reported that nothing was done while others didn't know what could happen.

When someone is overexposed to radiation, they are given radiation leave days of 28 working days (KI)

CHAPTER 6 DISCUSSION OF FINDINGS

The Ionising Radiation Protection (Amendment) Act, 2011, read as one with the Ionising Radiation Protection Act, 2005 gives guideline on radiation exposure in Zambia. Regulation 4 in the first schedule gives the occupational exposure limits. The annual radiation effective dose exposure limit is 50mSv and monthly monitoring level is 1.2mSv.

For this study, the average monthly radiation dose for the period reviewed (2013-2015) was 0.58mSv which is below the lower monthly monitoring investigation level of 1.2mSv, although 5.3% of those included in our analysis had levels above this threshold. Much as the mean dose was found to be below the monitoring level, taking into account the linear, no-threshold dose–response approximation, no dose is regarded as completely safe. Therefore, these dose limits cannot delineate dangerous from safe and are not efficient as tools to minimize radiation risks.

Klerv, et al. (2015) conducted a retrospective cohort study that looked at the risk of cancer from occupational exposure to ionising radiation. The study enrolled workers from France, the United Kingdom, and the United States (INWORKS). The study provided a direct estimate of the association between protracted low dose exposure to ionising radiation and solid cancer mortality. For all cancers, they found excess relative rate of 0.51 per Gy (90% confidence interval 0.23 to 0.82). The study concluded that although high dose rate exposures are thought to be more dangerous than low dose rate exposures, the risk per unit of radiation dose for cancer among radiation workers was similar to estimates derived from studies of Japanese atomic bomb survivors. Thus this is a clear indication of an existing risk resulting from exposure even at protracted doses.

According to the regression coefficients, being at CDH was associated with reduced mean radiation dose of 0.21mSv and this reduction could be as low 0.01mSv or 0.41mSv, taking into account the sex of the worker. There could be several reasons for UTH having higher radiation reading, one explanation could be the working hours. There is an association between the workers exposure levels and time spent on a procedure. In one study, the fluoroscopy time was independently associated with the operator's radiation exposure dose (Maja et al, 2013). Cancer disease hospital has

been operating as an outpatient unit, as such patients are only attended to during normal working shift of 08hours (08:00hrs to 16:00hrs). UTH on the other hand operates on a 24 hour period divided into 8 hours working shift. However due shortage of human resource, some workers have to cover more shifts. From the survey, workers at UTH reported to have long working hours. This was one theme that emerged when workers were asked about the cause of existing exposure levels.

Another possible explanation of the high radiation dose at UTH is the state of equipment. A malfunctioning or an inadequately maintained equipment can cause or lead to exposure of radiation. Protective equipment including aprons, gloves, and collar shield have the ability to attenuate the radiation beam and hence are useful in radiation protection. Faulty equipment has a positive correlation to higher limits of exposure. Workers at UTH complained of poor state of equipment. Much as this research did not categorically assess the state of the equipment, this could be a possible explanation of the existing levels.

It was not established as to why females had a higher radiation dose than male workers. This may be related to the amount of time these workers spend in radiation environment. However, in terms of possible health effects, it has been suggested that men and women are may not be affected differently by radiation exposure. In a study that looked at the relationship between occupational radiation exposure and thyroid nodules, it was found that Thyroid nodules were significantly more prevalent in females in the control group (30.1% in females vs. 19.6% in males; $p < 0.05$). However, no such difference was observed between females and males of the case group (19.7% vs. 25.4%; $p > 0.05$) (Atoosa et al, 2012).

At the a mean dose of 0.58mSv, the solid cancer risk calculation estimated a life time risk of 8.4×10^{-4} and an annual risk of 1.6×10^{-5} at 0.6 mSv. At the monitoring level of 1.2mSv, the lifetime risk was 2.8×10^{-2} and annual risk 5.4×10^{-4} respectively. Estimates of the long-term health risks from ionising radiation are based largely on studies of the survivors of the atomic bombings in Japan in which more than 60% of exposed survivors received a dose of radiation of less than 100 mSv (the definition of low dose) (NRC, 2006; ICRP, 2007; UNSCEAR, 2008). These risk estimates have not been compared to the average in the general population, and the possible health worker effect. The cancer risk estimate from our study suggest low risk,

because the risk is comparable to risk due to natural exposure, however this should not be taken to suggest safety as there are always variances in existing circumstances.

Similar results were obtained by Andersson and colleagues (1991) in a study which looked at the cancer risk among staff at two radiotherapy departments in Denmark. They found an average cumulative radiation dose of 18.4 mSv. The overall relative risk was 1.07 (95% CI 0.91, 1.25) for all cancers, and no significant dose-response was observed. The risks for cancers that were considered radiation sensitive were not elevated.

There were notable variations in radiation doses between occupations. Radiographer had the highest radiation dose of 0.67mSv (0.86 SD), Nurses had mean dose of 0.44mSv (0.16 SD) Radiologist had mean dose of 0.38mSv (0.26 SD) and medical Physicist had the lowest mean dose 0.42mSv (0.15 SD). Studies have indicated that the amount of radiation a worker receives is associated to type of procedures they undertake as well as the time they spend per procedure. In one study done by Muja et al, (2013) they found that the type of procedure, the patient's body mass index, and the fluoroscopy time were independently associated with the operator's radiation exposure. Therefore workers conducting different procedures are likely to be exposed to different levels of radiation dose. Much more also, radiographer are more likely to attend to more patients in radiation rooms compared to medical Physicist and nurses. The observed average doses were below the radiation monitoring levels set for UTH and CDH. However there were individual exposures that were above the monitoring levels.

The respondents demonstrated good understanding of possible health effects due to radiation exposure. They mentioned a wide range of such possible health problems. However, of the 29 workers that participated in the survey, 19 (63%) indicated that they did not know the annual exposure limit, 37% indicated incorrect limit dose. More also, the respondents indicated that they did not fully understand the radiation safety guidelines and hence could not confidently say they followed the standard operating procedures. During the key informant interviews, the Radiation Protection Officers explained the regulations well highlighting the monthly and annual limits and safety precautions which should be standard practice. This knowledge did not

seem to be shared among the other workers. This suggests a knowledge gap in radiation safety.

The workers perceived the radiation levels to be high however this did not seem to translate into safety consciousness. The respondents did not show any safety seeking behavior, suggesting that the overall safety of the work environment was a responsibility of management and there was little they could do. More needs to be done to enhance safety consciousness.

Limitations and Strength of the study

This study has the following limitations: Firstly, the results can only be generalized to University Teaching Hospital (UTH) and Cancer Disease Hospital (CDH) because the data collected only represents the two institutions. Secondly the cancer risk estimates may not be precise because of the sample size used. Protracted dose require large sample sizes to be able to have accurate risk estimates.

However, this is the first study to estimate the radiation dose exposure at UTH and CDH using TLD readings. This study used standardized dose results as recorded by the Radiation Protection Authority of Zambia thus enhanced internal validity. The study also combined both qualitative and quantitative methods; this strengthened and broadened the findings by bringing out details that one of these methods, applied independently may not have managed to gather.

Recommendations

There is need for appropriate education and training of personnel in principles of radiological protection. This is particularly important because some proportions of the practitioners undertaking interventional practice at UTH and CDH are not radiologists or radiographers by training but have specialized in other areas. Furthermore, there is need for close collaboration between the interventionist team and the medical physicists.

There should be a more systematic and comprehensive radiation monitoring system at both institutions. We further recommend for an improved electronic record management system at both institutions so that dose monitoring is consistent

There is need for a maintenance system and regular internal audits/inspections of various radiation sources, equipment and facilities which is well documented. This system should ensure that supervision is provided and all equipment is correctly maintained and tested regularly.

There should be a feedback mechanism, where after the TLDs are read, workers are informed of the results. This should apply all the time even when the dose levels do not high to warrant an investigation.

All workers in radiation environment should be provided with a TLD badges. The Radiation Protection Officers should ensure that that these badges are worn consistently and correctly by all workers.

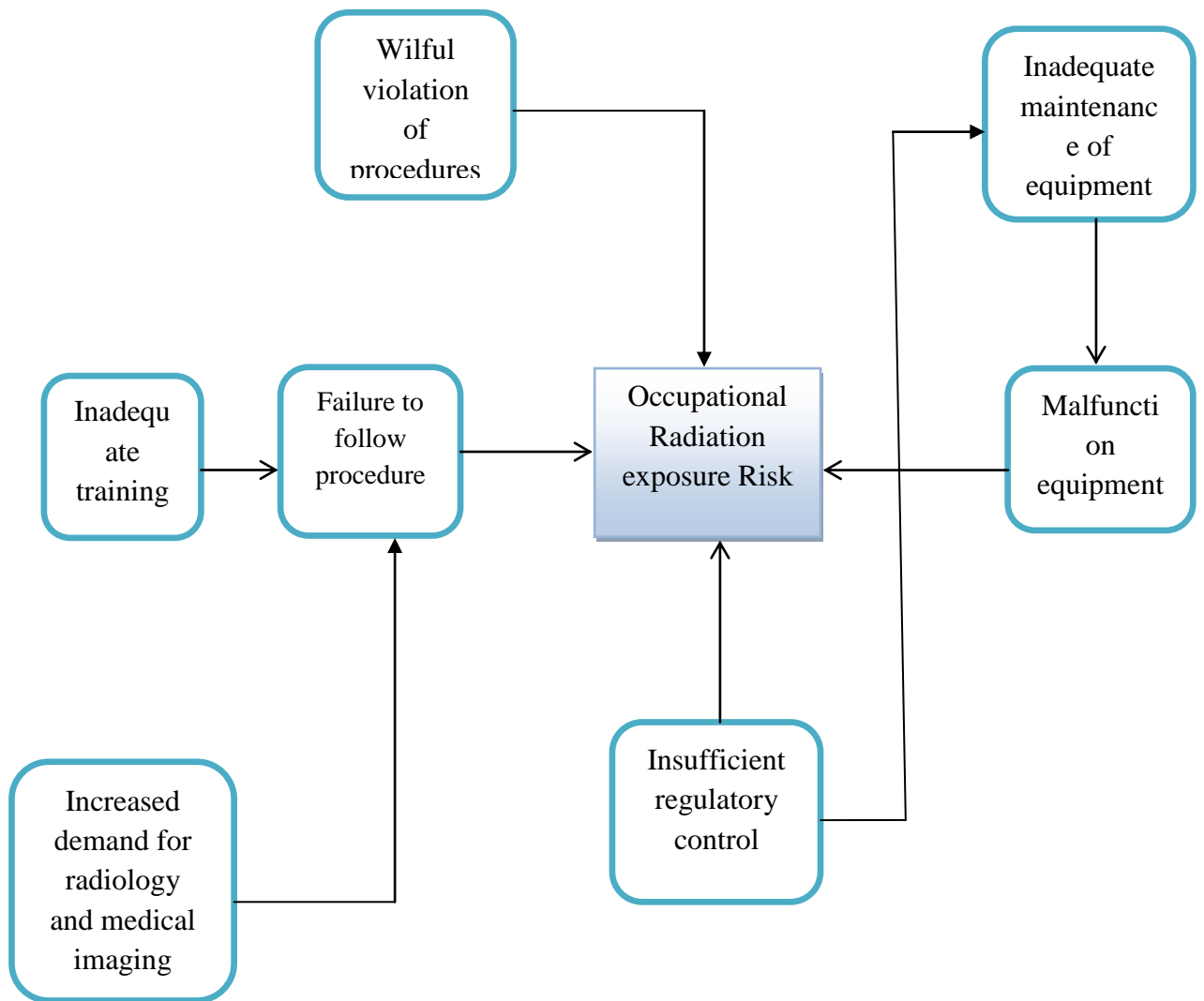
Conclusion

Effects of Ionising radiation have been investigated before and possible health effects due to protracted doses are established. The BIER states that it is unlikely that there is a threshold below which cancers are not induced, but at low doses the number of radiation induced cancers will be small.

This study has shown that radiation doses received at UTH were slightly higher than those received at CDH; however this was within acceptable limits for occupation exposure. Monitoring of occupational radiation exposure is an ongoing process and should be strengthened due to the potential risk of high exposure. With the continued demand for radiology services, there is need to enhance occupational radiation protection. No lives should be risked even when saving lives

Conceptual framework

Formulated after considering concepts coming out of literature



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ANNEX

Annex 1: Consent form

The interviewee information and consent sheet

Title of the study: Occupation Radiation Exposure on Radiographers and Radiologists: Levels and Risks at University Teaching Hospital and Cancer Disease Hospital, Lusaka

Introduction

I am Given Moonga, a student at the University Of Zambia School Of Medicine undertaking this study for the partial fulfilment of the Master of Science in Epidemiology and Biostatistics.

Purpose of the study

You are invited to participate in this Research. The information from this research will be useful in analyzing the levels of occupation radiation exposure and risks posed by the existing levels.

There is a questionnaire which has been designed for you to answer as an individual. I will provide any clarification if you do not fully understand the question(s). The questionnaire will take a few minutes to answer. The answers to the questions will be treated with confidence and your name will not appear anywhere.

Risks

The study has low risks because it simply assesses your perception on the occupational radiation exposure. Very few personal questions will be raised, of which will be treated with strict confidentiality.

Benefits

This study will help better understand risks of occupational exposure and will help improve radiation safety to workers.

Voluntary participation

You have the right to withdraw or refuse to participate in the study before answering the questionnaire or during the course of answering the questionnaire.

Thank you for your willingness to contribute to the success of this research. For any clarification feel free to contact me or University of Zambia Research Ethics Committee (UNZAREC).

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Telephone: 260-1-256067

Consent sheet

The information about this research has been explained to me clearly. I understand the purpose, its procedures, the possible benefits and risks. I hereby consent myself to participate in the research.

Name:

Signature:Date:

Witness

Name:

Signature:Date:

Annex 2: Questionnaire for Radiographers and Radiologists.

Interview Schedule

Remember to:

- Introduce Yourself.
- Explain purpose of study.
- Get Informed Consent.
- Ensure Confidentiality.
- Thank the respondent after interview.

Respondent's identification (Serial Number)

Date

Hospital

Section A: Background information

Please tick where appropriate (✓)

1. (a) Sex: Male () (b) Female ()

2. Marital status

a) Single ()

b) Married ()

c) Divorced ()

d) Widow ()

e) Widower ()

3. How old were you at your last birthday?

4. How long have you been working at this Hospital in Radiology Department?

5. Have you worked in a similar radiation environment before apart from this hospital?

a) Yes ()

b) No ()

If no skip to question 7

6. How long have worked in radiation environment?

7. How many children have you had while working in any radiology department?

8. Did any of the children have conditions that could be related to radiation exposure?

a) Yes ()

b) No ()

9. If your answer to the above question was yes, what condition(s) did they have?

.....
.....

Section B: Radiation Safety

10. How much radiation do you think you are being exposed to in your environment (with regards to the limits)?

.....
.....
.....

11. What factors do you think could lead to the existing levels of exposure at your work place?

.....
.....
.....
.....

12. What factors do you think could lead to over exposure to an individual worker?

.....
.....
.....
.....

13. Have you ever been accidentally been over exposed to radiation during your time at work?

a) Yes ()

b) No ()

14. Do you understand the radiation exposure guidelines?

a) a) Yes ()

b) b) No ()

15. Do you think guidelines are adequately followed? Explain your answer.

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Section C: levels of Knowledge

16. Have you received any radiation safety training? a) Yes () b) No ()

17. How often do you wear the radiation badge when you are at work?

a) All the time ()

b) Sometimes ()

18. What is done to workers who do not wear badges while at work?

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19. Do you think occupational radiation exposure could have effects on your health?

a) Yes () b) No ()

If no skip to question 21

20. What health problems do you think can be caused by these levels of exposure?

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21. Do you know the annual occupational radiation exposure dose limit?

a) Yes ()

b) No ()

22. What is the annual exposure limit?

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23. Are you given any feedback on the levels of exposure after radiation monitoring is done?

a) Yes () b) No ()

24. If your answer to the above question was yes, what kind of feedback are you given? Please explain.

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.....

25. What happens to you if you have an overexposure?

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.....
.....

26. Do you have any associates that represent your interest with regards to exposure?

a) a) Yes ()

b) b) No ()

Thank you for participation

Data extraction check list

1. Date
2. Hospital a) UTH () b) CDH ()
3. Serial Number (S/N).....
4. (a) Sex: Male () (b) Female ()
5. Marital status
 - a) Single ()
 - b) Married ()
 - c) Divorced ()
 - d) Widow ()
 - e) Widower ()
6. Type of work
7. Radiation dose.....
8. Radiation acquired age.....

