RADIATION SAFETY IN DIAGNOSTIC RADIOLOGY PROCEDURES USING X-RAY IN MEKELLE CITY. A CASE OF GOVERNMENTAL AND NON-GOVERNMENTAL HOSPITALS

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Abstract. Ionizing radiation has enough energy to damage DNA and increase human risk of developing cancer. Radiation protection must be assured to all the people of the hospital, from the employing authority to the workers carrying out radiological procedures. This work aims to evaluate the radiation safety in diagnostic procedures using X-ray, in Mekelle city, in the case of governmental and non-governmental hospitals. All the data are collected by observation and interviewing the staff members of each facility, measuring the dose rate at the controlled and supervised areas, the outputs and leakage of the X-ray machines. The collected data are evaluated both qualitatively and quantitatively. The result shows that 25.9 % of the radiation workers are females, and 74.1 % of them are males. As concerns the educational background, 37 % of the workers are bachelor degree holders, and 63 % are possessors of university diplomas. Thermoluminescence dosimeters (TLD) produce a file on the procedures being practiced for the assessment of personal doses. A need for such a file has also been touched to ensure the uniformity in processing of dosimeters, recording and reporting of doses by different TLD. It was noticed that there is a problem in using the existing protective devices during the radiotherapy practice. To improve the radiation safety procedure, the lifetime of the X-ray machine has to be limited. Also, it is necessary to adjust the maintenance and service shop to control the X-ray machine. At the same time, the radiation workers must permanently update their knowledge and skills.

Key words: X-ray, radiation, safety, radiological procedures, hospitals, clinics, TLD.

INTRODUCTION

Medical imaging has substantially improved both the diagnosis and treatment of medical conditions in human beings [13]. There are many types or modalities of medical imaging procedures, such as computer tomography (CT), magnetic resonance imaging (MRI), fluoroscopy, mammography, each of which uses different technologies and techniques [2]. Many imaging procedures use ionizing radiation to generate images of the body. The benefits of ionizing radiation to the patient are

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considerable in terms of comfort and diagnostic effectiveness. However, X-ray examinations can be expensive and potentially hazardous [17].

To implement the standard set by Ethiopia Radiation Protection Authority, one needs an effective radiation safety infrastructure, regulations, and an efficient regulatory system [3]. This can be supported by experts and developing safety culture [14]. The basic safety standard covers the application of ionizing radiation for all practices and interventions [23].

International atomic energy agency (IAEA) has established the control and implementation of the ionizing radiation sources to protect the public from radiation risk by setting the guideline in using the radiation and applying basic safety standards in all member countries. Ethiopian radiation protection agency (ERPA) is the authority that adopts the basic safety standards to all Ethiopian sectors using ionizing radiation. ERPA sets requirements to use ionizing radiation to control and monitor all the country facilities. That is why we need to search the application of safety standards in health facilities of Mekelle city.

Diagnostic radiology is now a widely used technology in hospitals and other health institutions in Ethiopia [18]. Health institutions in Mekelle is also using the diagnostic technology for the last several years. However, the quality of the service has been impeded due to several limitations [18]. The health institutions usually operate their machines by mid-level health professionals who were trained for a short time at the Diploma level. The government has to improve this mentioned gap by offering training for the radiation workers [5].

Therefore, this work aims to evaluate the radiation safety in diagnostic radiological procedures using X-ray in Mekelle city in the case of governmental and non-governmental hospitals.

MATERIALS AND METHOD

STUDY AREA

The safety standards in diagnostic radiology procedures using X-rays are conducted at the radiology department of Ayder comprehensive specialized hospital, Mekelle referral hospital Mesekerem ben general hospital, Romanat primary hospital Kudus, and Semehal higher clinics. All the mentioned hospitals and clinics are situated in Mekelle city. They are providing the radiological images for the diagnostic purpose.

Fig 1. Map of the study area obtained from Google map.

This study consists in a quantitative and qualitative method for data collection by observation and interview. Both modalities are used for data analysis for the period, January–May 2021. A sampling survey, involving medical diagnostic X-ray workers, was conducted in six government hospitals and higher clinics. There are four procedures performed to collect the data. First, data are collected by observation and interviewing the staff members. Second, are the measuring the dose rate at the controlled and supervised areas, the layout checking and the necessary classes of the exposure facility, checking appropriateness and existence of the protective devices (such as shielding, TLD recording). Third, checking the quality performance of the machines output, leakage of the machines, evaluating the request paper prescribed by the medical specialist. Finally, checking the record of the facility receptions is necessary. To measure the leakage and machine output of the radiation survey, the multi dosimeters were used.

RESULTS

In this study, a total of six facilities found in Mekelle city were studied. Two of them are governmental hospitals, namely, Ayder specialized hospital, a medical school and referral hospital and Mekelle general hospital, a zonal referral hospital. The other four facilities are private (non-governmental) which are Meskerem ben general hospital which serves as a school of medicine, Romanat primary hospital, Semehal higher clinic, and Kudus higher clinic. In all these facilities there were about 27 radiation workers (radiographers) providing the radiological diagnostic images for the patients. About ten parameters were implemented in studying the application of radiation safety standards in processing the radiological diagnostic images using X-ray machines in all facilities as shown below.

EDUCATIONAL BACKGROUND AND SEX OF RADIATION WORKERS

As it is shown in the Table 1, the total numbers of radiation workers in the hospitals and clinics and the research centers are 27 from which: radiation workers 7 (25.9 %) are females and 20 (74.1 %) are males. In the case, of educational background, 37 % of the total workers are degree holders (10 % are females and 90 % are males), and 63 % are diploma graduates (35.3 % females and 64.7 % males). This indicates that the participation of females is very low and also, a few numbers of degree holders are females. As the radiation worker has more knowledge, his/her awareness in radiation protection and protecting radiation risks also is higher. All the possible radiation protection protocols will optimally apply, minimizing the risks associated with exposure to ionizing radiation.

Table 1

Educational background of radiation workers

Name of facility	Diploma		Degree		Total
	Male	Female	Male	Female	
Ayder specialized hospital	6	4	1	–	11
Mekelle general hospital	1	2	4	1	8
Meskerem general hospital	–	–	2	–	2
Romanat primary hospital	2	–	–	–	2
Semehal higher clinic	–	–	2	–	2
Kudus higher clinic	2	–	–	–	2

WORKLOAD FOR EACH FACILITY

Workload is a measure of radiation output and gives a sense of utilization of a particular machine. It is the projected absorbed dose delivered to the isocenter in a specified time. The workload, *WL*, is defined by the following equation:

$$WL = I \times t \times n_0 \times n_\mathrm{i} \times d \quad (1)$$

where I is the current intensity measured in milliampere, t is defined as the exposure time in seconds, n_0 represents the average number of patient, n_i is the number of images per patient which is six and d is the number of days per week which is five. Workload uses the units mA-min/week [1, 20, 21].

Milliampere-seconds, also more commonly known as *mAs*, is a measure of radiation produced (milliamperage) over an amount of time (seconds) via an X-ray tube. It directly influences the radiography optical density, when all other factors are constant.

$$mAs = I \times t \tag{2}$$

Therefore, the total milliamperage, *TmAs*, is given by:

$$TmAs = \sum_{i=1}^{n} mAs \times p_i \tag{3}$$

where p_i is the number of procedures in one week, and *n* is the number of days per week.

Table 2

The workload of radiation workers

Facility	Total mAs per week	Total mA-min per week	Work load (mA-min per week)
Ayder specialized hospital	6558.60	109.31	9.94
Mekele general hospital	2189.20	36.49	4.56
Meskerem general hospital	1440.00	24.00	12.00
Romanat primary hospital	3337.50	55.63	27.81
Semehal higher clinic	4582.92	76.38	38.19
Kudus higher clinic	435.76	7.26	3.63

The workload in each hospital and clinic is calculated and is less than 40 mA-min per week as shown in Table 2. In Ayder specialized hospital, the total workload per week is relatively smaller than in the Semehal higher clinic. This does not mean that the number of individuals treated per week in Ayder is less than in the Semehal clinic whereas, Kudus higher clinic workload is relatively smaller than the rest of the facilities.

QUALITY OF THE MACHINE

A high quality of a machine means that the photons are emitted with the necessary amount of energy used for diagnostic or therapeutic purposes. The energy of the photon depends on the potential difference, in kV, the amount of current in mA, and the duration (time) of exposure in seconds or milliseconds. Therefore, to evaluate the quality of the X-ray machine, the kV and time deviations are considered.

Kilovolt deviation of facility

Deviation of the kV is calculated using Eq. (4) and divided by the input kV and multiplied by 100 % [4, 21]:

$$\sigma_v = \frac{v_{in} - v_{out}}{v_{in}} 100 \tag{4}$$

where v_{in} is the machine input voltage given in kV, v_{out} the average output of the machine measured in kV, and σ_v is the standard deviation expressed in terms of percentages.

Table 3 shows the standard deviation of the kV of the X-ray machine. The increasing and decreasing of the kV had an impact on radiation safety in processing the diagnostic radiological image.

Table 3

Kilovolt deviation of facilities

Facility	σ_v (%)					
	50 kV	60 kV	70 kV	75 kV	80 kV	90 kV
Ayder	+3.20	+3.67	+4.57	+5.60	+6.00	+2.67
Mekelle	+2.50	+1.97	+2.54	–6.13	–2.25	–8.22
Mesekerem	+17.30	+7.58	+8.00	+7.80	+7.50	+4.89
Romanat	+2.20	+5.25	+7.50	+3.47	+12.13	+9.11
Semehal	–5.10	–1.83	–3.93	+0.34	+0.56	–2.06
Kudus	+17.20	–8.53	+8.93	+6.93	+7.25	+3.61

The kV of the machine affects the quality of the radiological image. As the kV varies, the energy of radiation also varies. During the procedure of the radiological image acquisition, the exposed organ of the body will tolerate a fixed amount of energy. If the amount of energy is different from the fixed amount of energy, the radiological image of the organ or part of the body will not be clear.

Time deviation of the facility

Time deviation is given by Eq. (2) mentioned in [18, 19]:

$$\sigma_t = \frac{t_{in} - t_{out}}{t_{in}} 100 \tag{5}$$

where t_{in} is the input time of the machine, t_{out} is the average output time of the machine, and σ_t is the standard deviation in terms of percentage.

Table 4 shows the time deviation of each X-ray machines of the facilities.

Table 4

Time deviation (σ_t) of the facility

Input time (ms)	Ayder specialized hospital	Mekelle general hospital	Mesekerem general hospital	Romanat primary hospital	Semehal higher clinic	Kudus higher clinic
63		0.00				
71		+1.27				
80		0.00				–4.94
90		+0.33				
100		0.00				–4.00
120					–5.13	–21.54
150			+0.87	–2.83		
160						–2.56
200				–2.00	–2.08	–2.79
250			–1.56	–1.44		
260						–7.25
300			–41.02	–1.40	–1.45	
400	+0.11		–0.74	–0.94	–0.96	
500			+1.23	–52.94	–0.34	
1050	–4.77					
1070	–6.50					
1150	–3.48					
1210	+1.12					

When the machine exposing time of an organ or part of the body increases or decreases, the amount of ionizing radiation received by the organ or the part of the body are also increased or decreased. The exposure time is limited by the amount of energy received by the organ or part of the body and is a risk factor associated to irradiation. The accuracy of time has also, a vital role in the quality of radiological image. To have a high quality of radiological image for medical purposes, the machine deviation must not exceed ± 10 %. The results shown in Table 4 indicates that the time deviation of the Romant primary hospital is −52.94 % which is less than 500 ms whereas, at the Kudus higher clinic was 21.45 % at 120 ms. In all cases, the procedures operating with these times will expose the organ to a risk associated with radiation exposure.

DISCUSSIONS

According to [4, 9−11, 16] the effective and efficient use of shielding materials and the development of optimal design require a qualified expert for performing either the calculations or the evaluation and result reviewing. However, the results obtained in this work, shown in Table 1, are beyond this expectation because the number of qualified experts is lesser than the required one. This shows that the performance of radiologists in all selected hospitals and clinics are relatively poor according to [1, 5, 6].

In principle, when the radiation worker has exposed a patient to ionizing radiation, whatever he/she uses a protective device, he/she will be exposed, too, to a minimum dose as compared to the patient but, the successive exposures to radiation have a cumulative effect. To protect the workers against such a radiation risk, the principle of radiation protection is to limit the workload per radiation worker. The result obtained in this work shows that, the limit must be below de value suggested by [4, 10]. The regulatory body recommends that the workload of the radiation workers not exceed 40 mA-min per week and the facilities workload of each radiation worker must be lesser than 40 mA-min per week [4].

When the organ or part of the body is exposed multiple times, to a less and very high amount of energy, they receive and absorbs energy which damages the chemistry of the cells of these organ or part of the body. To avoid or minimize the risk associated with the exposure, the principle of radiation protection and the requirement regulatory body recommends that the deviation of kV of the machine not exceeds ± 10 %, this including a quality testing of the machine [4, 21]

Moreover, the kV deviations of the other three machines were out of the range of the requirements, set by the regulatory body at 50 kV. The voltage deviations of X-ray machine, at Meskrem hospital and Kudus higher clinic, were +17.3 kV and +17.2 kV respectively.

The 80 kV machine at the Romanat primary hospital has a deviation of +12.13 kV and was not accepted. When the X-ray machine operating at 80 kV, the organs of the body are exposed at high risks [4, 12, 15]

LEAKAGE OF RADIATION

In all facilities, the leakage of radiation at the main gate to the exposure room and all accessory doors does not exceed the amount for public dose per annum, that is 1 mSv [3]. This is the place or area that the patients, supporters, and non-radiation workers are frequently sitting. Through the control room lead glass window in the area where the radiation worker appeared, the amount of dose leaking is not exceeding the limit allowed for a radiation worker which is limited by the regulatory body at 6.5 mSv per hour [4, 9–11]. In all cases, the principle of radiation protection helps not to reach ionizing radiation to the unnecessary area and unnecessary exposure is not allowed. Accepted dose leakage and the amount and dose limited is permitted by the regulatory body based on the procedure and category of the ionizing radiation source [4, 9–11].

MACHINE HISTORY AND MANUFACTURED DATE

Different countries are producing and fabricating medical equipment and radiating machines like X-ray machines for diagnostic and therapeutic purposes. The quality of the fabricated medical equipment depends on the technology of the countries as well as their cost. All used machines in all Mekelle facilities are made up in China but the date of their manufacturing is not noted, this leading to difficulty in their maintenance. As the machine gets old, the emitted photon energy will not be consistent and is difficult to predicate the dose emitted. As a result, the application of radiation protection makes it difficult and gets failed.

Radiation protection materials

In all the facilities, the protective devices like a lead apron, gonad shield, lead eye goggle, and lead glove physically exist to satisfy the requirement of the complaints and to get the license from the authority. From the observation of the researchers, the number of existing protective devices is not enough in all facility excepting Ayeder specialized hospital and Mekelle general hospital. This shows that the purpose and application of the protective devices are not implemented properly, because the disabled patients will need a person who assists them to have the right position during the procedure. The patient and supporter need shielding to protect unnecessary exposed organs or parts of their body. The number of the protective device is not enough to apply the principle of radiation protection. For not shielded and protected people using the protective devices in the procedures of the diagnostic radiological image, the risk of radiation is maximized.

The TLD reading in all facility

The thermo luminescence dosimetry of the people working with radiation were measured in the last four months. Due to an instability in the region, we were not able to read the other TLD file of some of the workers. This implies that we were not able to understand their status of exposure to ionizing radiation. In such cases, the radiation protection principle is not applied and the risk associated with it will be maximized.

Dark room facility

The facility of dark room in Ayder, Mekelle, and Meskerem hospitals were absent. They use digital images meaning that they used automatic and digital imaging processors. Romanat, Semehal, and Kudus centers use dark room image processors. During the observation, the main component of the facilities like chemical thermometer, automatic timer, darkroom was not available. The radiographer is at the same time a dark room technician [4, 6–9, 14]. The dark room procedure is very important in having a quality radiological diagnostic image if the process is perfect and operated in the right principle. Darkroom was one of the most important elements in order to obtain a quality of image and read the films [9–11, 15].

Request paper/prescription

The requested paper or the prescription letter for the diagnostic radiological image is evaluated based on justification, optimization, and dose limit. The main thing in this request paper must satisfy all the mentioned principles mandatory for radiation protection and in order to minimize the risk of radiation [1, 22, 23]. The requested paper was evaluated. The main information like the dose limit were not mentioned. The researchers have noticed that a lot of children and mature females are exposed to ionizing radiation. All these groups need high prevention and care during the procedures during diagnostic imaging. But, when we look at physician's written prescription, there is no any information about the patient protection against the unnecessary radiation exposure. The data collected by interviews show that the medical practitioners forced a multiple exposure for a single case. This shows that optimization procedure was not taken into account due to the patient potential risk.

Implementation of radiation protection

The principles of radiation protection are not yet properly implemented in all Mekelle facilities. The observation shows that the radiographer did not wear the lead apron and other protective devices during his/her work. Moreover, he/she did not shield the unnecessary part or organ of the patient. Generally, the way of application radiation protection for the patient and the radiation worker is risky, contrary to the guidelines set by [4].

CONCLUSIONS

The education of the radiation workers/radiographers is low and no dark room technician at the facilities of analog machines demanded the dark room process. The lifetime of the X-ray machines is not known and limited. The leakage of radiation is below the limited dose which is permitted by the regulatory body and the principle of radiation protection of IAEA. The workload of the radiation workers is also below the permitted mA-min. In some specific X-ray machines, the proper kV and time deviation are attained, that is, the deviation is beyond the limited value of standard. TLD produce a duly approved document on the procedures being practiced for the assessment of personal doses. A need for such a document will ensure the uniformity in processing of dosimeters, recording, and reporting of doses by different TLD units and provide guidelines regarding the infrastructure requirement. Lack of such device means that a great care could not be taken by the responsible persons. Therefore, all the concerned body should implement this principle to improve the quality of the services. Darkroom and the sufficient materials were not available in some hospitals. The requested paper was not clearly stated according to the principles.

RECOMMENDATIONS

Based on the obtained results, we recommend the following points:

1. To update short and long-term programs of the radiation workers, that must be adjusted to maximize their knowledge in radiation protection and use of ionizing radiation.
2. To frequently inspect the X-ray machines and their facilities according to their lifetime and graded approach.

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