ISSN: 0975-766X
CODEN: IJPTFI
Available Online through *Research Article*
www.ijptonline.com

THE EFFECT OF CHRONIC LOW-LEVEL EXPOSURE ON HAIR DAMAGES OF RADIATION WORKERS

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Received on 02-08-2016 *Accepted on 28-08-2016*

Abstract

According to chronic exposure of radiation workers during their work experience, this study was an attempt to assess the damage caused by radiation on the hair of radiation workers. In this study the total Skin and Hair Analyzing System capable of registering polarized images was used for measuring hair parameters (hair thickness, hair root, hair nutrition, hair status and hair oil). Hair management software , Skin Management Software and also 150X, 700X lenses were used to measure the hair parameters. The study included one questionnaire which it's face validity and content validity was approved by pilot study and some professional experts. The participants were 152 hospital personnel and were divided into radiation exposed group (radiotherapy technicians, nuclear medicine technicians) and control group (nurses) and were homogenized based on age, work situation, work time, work experience and baldness (family history). Results showed that chronic exposure causes the reduction of hair thickness in female radiation workers than nurses. The hair root, hair nutrition, hair status and hair oil in groups showed no significant difference to each other. However, there was no significant difference in hair parameters between male radiation workers and male non radiation workers. Although attention to safety in working with radiation has increased, damage caused by radiation has not yet been reduced to zero. Results of the study showed that chronic exposure may cause damage to the hair of radiation workers. The reason may be inadequate training of technologists and their high workload.

Key words: chronic exposure, cell death, cell Apoptosis, hair follicle, radiation exposure

Introduction

Ionizing radiation from natural and artificial (man-made) sources of radiation has always affected human body on the Earth. In spite of the beneficial use of ionizing radiation, it can have harmful effects on humans. In this regard, the World Health Organization (WHO) is trying to confirm the theory that radiation advantages are more than its harmful side effects. The purpose of this program is to protect human health against the hazards of ionizing radiation and manage the use of it with more safety (1). However, since the principles of safety and security are to optimize the dose rate, it's not possible to ensure that technologists' exposures be reduced to zero. Studies have shown that the rate of chromosomal mutations is more in technologists than other people (2, 3). These mutations are in stable form (4). Moreover; cyclic and dysenteric mutations are observed rarely because the amount of chronic exposure in each session is low.[3] Although the technologists absorbed dose is low, their whole body receives exposure and therefore there is a possibility of cancer for each tissue (5). The amount of genetic aberrations in the range of diagnostic radiation (50- 100 Kev) is two to three times a larger than high energy radiation.[2] This can cause a somatic mutation. Therefore following the safety of work with this range of radiation is very important. The biological control of somatic mutations in human is very important because somatic mutations cause cell death, reduction of special performance and the development of cancer (6).

Follicles are part of the epidermis and pass the growth cycle to produces hair. Hair follicles because of short cell cycle duration (between 10 and 24 hours) are sensitive to radiation especially during their growth cycle (7, 8). Apoptotic cells can be observed in growing follicles from 3 to 24 hours after irradiation. Maximum number of apoptotic cells is seen about 12 hours after irradiation (7, 9). Significant increase in the number of apoptotic cells has been observed in irradiated hair follicles. These effects caused morphological changes in hair thickness (7). Furthermore, discoloration and white hair were observed in hairs which grew again after irradiation in mice. These color changes were permanent (10). Reduction of volume and thickness of hair may be indicative of sensitivity of hair to irradiation. Any loss in producing cell because of delay in mitotic cells or cell death can lead to a reduction in the hair thickness that is known as hair dysplasia or it can cause the growth of abnormal hair (11). Hair loss was one of the first radiobiological responses which was reported in 1896 by Daniel (12). Hair can also be used to determine the absorbed dose at the surface of the body. Because of easy access, sensitivity to irradiation and keeping the damage for a long time hair can be used as a biological dosimeter (7).

Also they are exposed to irradiation more than other tissues. However, until now no research has been done on the possible abnormalities caused by chronic exposure on technologists' hair. Therefore, the aim of this study was examine the relationship between work experience of radiation exposed groups and their hair damages. Accordingly, this study investigated the hair damages caused by chronic exposure to radiation on radiation exposed groups throughout their work experience. The results of this study can have implications for designing new ways to reduce these side effects.

Materials and Methods

The participants were 152 hospital personnel (66 male and 86 female). These included 48 radiotherapy technicians, 23 nuclear medicine technicians and 81 nurses. Personnel were divided into radiation exposed groups (radiotherapy technicians, nuclear medicine technicians) and control group (nurses). All the participants were homogenized based on age, work situation, work time, work experience and baldness (family history). This procedure was approved by the ethical committee of the Shahid Beheshti University of Medical Sciences.

Inclusion criteria: Participants signed informed consent and had 24 to 55 years of age.

Exclusion criteria: Family history of baldness; specific disease; menopausal women and women had a hysterectomy or their ovaries were removed. The Investigation included a self administrated questionnaire that its face validity and content validity was approved (Supplementary file). Correlation coefficient and cronbach's alpha values in test- retest were estimated 0.80 and 0.75 respectively. First written consent was obtained from all participants and then questionnaire details were described for each of them. Then the participants were asked to fill out the questionnaire carefully.

In this study was used Total Skin and Hair Analyzing System (Tes-TB device) capable to register polarized images. This device been made by KC Technology Company, Korea. The device included hardware's such as 1X, 15X, 60X, 150X, 700X lenses, sensors to measure moisture, elasticity, fat, and software's such as Hair management software (HMS), Skin Management Software (SMS) and KC Camera (KC Cam) for measuring hair damages, skin damages and recording images respectively. In this study the HMS and SMS software's and also 150X, 700X lenses were used to measure the hair thickness, hair nutrition, hair status and hair oil. Tes-TB device with several lenses for showing skin and hair is very beneficial for clinical and academic studies of hair and skin tissues. To measure the hair parameters (hair thickness, hair root, hair nutrition, hair status and hair oil) polarized light was used which was one of the system features. Typical images are obtained from reflected light from tissue surface and inside of the tissue (The amount of light that penetrates in tissue)

while by using polarized light images from deeper tissues can be obtained and therefore remove the images of superficial layers of skin. This is very helpful for study hair and hair root junction that is located in skin depth. Additionally, this system had an independent source of polarized light which was used to study hair shaft (hair nutrition) and hair root independent of hair color. The polarized light in image receiver showed a picture that depending on hair structure (healthy to damaged hair) had a color between green to red (Figs 1, 2).

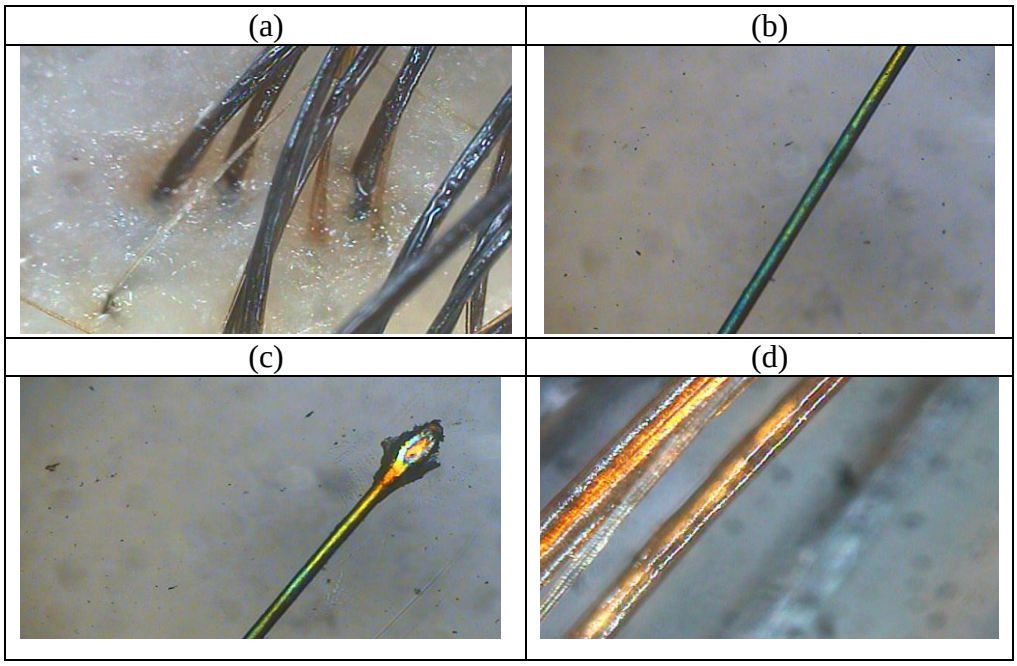

Figure-1. Normal hair. (a) Hair thickness with magnification of 150X. (b) Hair shaft with magnification of 150X (hair nutrition). (c) Hair root with magnification of 150X. (d) Hair status with magnification of 700X.

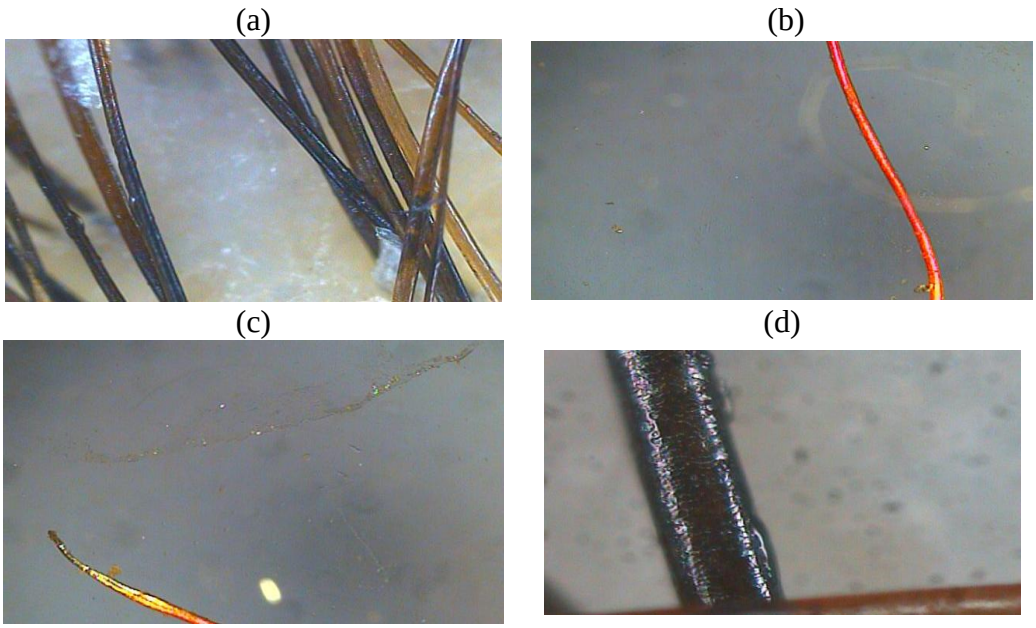

Figure-2. Damaged hair. (a) Hair thickness with magnification of 150X. (b) Hair shaft with magnification of 150X (hair nutrition). (c) Hair root with magnification of 150X. (d) Hair status with magnification of 700X.

After completing the questionnaire, by using Tes-TB device, some images were taken from different parts of subjects' head and hair parameters were measured. First, by 150X lens four images was taken from four major points of the head (frontal, occipital, temporal and vertex of head) and thickness of thickest hair in each image was calculated and then mean of hair thickness was recorded. To study the roots and hair shaft by 150X lens, a hair root was biopsied superficially and the desired parameters were evaluated. For checking the status and viability of cells in the hair, 700X lens was used. Finally for measuring hair oil, SMS software was used. For each person an oil pad was putted on the temple for 15 seconds and then the amount of fat with 150X lens was measured.

In order to classify hair root, hair nutrition, hair status and hair oil this system equipped to scoring of hair(13-15). Hair parameters were measured according to these criteria's. According to this scoring each of these parameters is divided to several main groups and these main groups include several subgroups. Due to the low number of participants in project, subgroups were not considered and just main groups were studied as a scoring. Therefore just main groups were carried out in table 1.

Table-1: the scoring of hair parameters.

Polarized hair-root	Hair nutrition	Hair status	Hair oil
1.normal hair	1.normal hair	1.normal hair	1. Dry
2.oily hair-root	2.small damaged hair	2.oily-dry hair	2. Neutral
3. hair-loos hair-root	3.worst damaged hair	3.small damaged hair	3. Oily
		4.mid damaged hair	4. Combination
		5.worst damaged hair	5. Very oily
		6.split hairs	

Various factors are involved in hair damage which was mentioned in the questionnaire. There were a lot of confounding factors that aggravate hair damage. Therefore we selected the personnel's that had a same situation in confounding factors. In this study in addition to descriptive statistics for variables, chi-square test, t-test and one- way analyze of variance (ANOVA) test was used for comparison between radiation exposed groups and control group. Data were analyzed using SPSS16.0 software. Furthermore, logistic regression was used to control the confounding effects and determine predicting

factors of hair loss. Unfortunately it was not possible to calculate the total absorbed dose of radiation exposed groups because some of them didn't use film badge continuously and some of them were working in several places and consequently did not have a certain dosimeter in each center. Therefore, their work experience was taken into consideration in this study.

Results

The mean age of the personnel participating in the investigation was 34.22 ± 8.12 years for radiotherapy group, 34.26 ± 9.74 years for nuclear medicine group and 32.53 ± 8.58 years for nurse group and their mean work experience was 9.9 ± 6.73, 8.19 ± 6.53 and 9.17 ± 7.36 respectively.

- **Comparing the hair parameters without regard to sex**

Hair parameters without regard to sex were measured and compared between three groups (48 Radiotherapy technologists, 23 Nuclear medicine technologists and 81 Nurses). The hair root, hair nutrition, hair status and hair oil in three groups showed no significant differences. However, the value of hair thickness had significant difference between radiation exposed groups and control group (Table 2).

Table-2: the comparison of mean of measured variables in 3 occupational groups without regard to sex

	Nurse	Nuclear	Radiotherapy	P-Value
Hair thickness	73.17±11.61	67.21±10.03	68.69±10.65	0.02
Hair root	2.50±1.32	2.82±1.30	`2.50±1.33	0.62
Hair Nutrition	1.51±0.83	1.55±0.84	1.72±0.93	0.41
Hair Status	1.60±0.76	1.65±1.07	1.68±0.74	0.85
Hair oil	2.45±0.89	2.34±1.02	2.50±0.87	0.80

- ***Comparison of female's hair parameters***

The female's hair parameters were measured and compared between groups (The number of females in each group was 28 Radiotherapy technologists, 14 Nuclear medicine technologists and 44 Nurses). Results showed that hair nutrition, hair status and hair oil in 3 groups did not have any significant difference. But, significant difference was observed between the hair thickness of female control group and female radiation exposed groups (Table 3).

Table-3: The comparison of mean of measured variables in three occupational groups with regard to sex.

	Nurse $\bar{X}$ ±SD	Nuclear medicine	Radiotherapy $\bar{X}$ ±SD	P-Value
Female				
hair thickness (µm)	78.49±9.48	68.80±10.17	69.79±1.41	< 0.01
Hair root	2.40±1.40	2.57±1.45	2.35±1.41	0.81
Hair Nutrition	1.45±0.76	1.50±0.85	1.85±1.00	0.52
Hair Status	1.59±0.62	1.57±0.93	1.75±0.79	0.91
Hair oil	2.54±0.84	2.50±1.01	2.35±0.95	0.69
Male				
hair thickness (µm)	66.85±10.80	64.75±9.88	67.16±13.03	0.86
Hair root	2.83±1.21	3.22±0.97	2.7±1.21	0.64
Hair Nutrition	1.59±0.92	1.66±0.86	1.55±0.82	0.68
Hair Status	1.62±0.92	1.77±1.30	1.60±0.68	0.80
Hair oil	2.35±0.94	2.11±1.05	2.70±0.73	0.54

- **The comparison of male's hair parameters**

The male's hair parameters were calculated in three groups (The number of males in each group was 20 Radiotherapy technologists, 9 Nuclear medicine technologists and 37 Nurses). Hair thickness, hair nutrition, hair status and hair oil in three groups did not have any significant difference (Table 3).

- **The study of Hair parameters in personnel with work experience over 5 years and under 5 years**

The results showed that irradiation only reduced the hair thickness of female radiation exposed groups. Accordingly, for completing the comparison, hair parameters were measured in personnel with work experience over 5 years and under 5 years separately. First hair parameters were calculated in personnel with work experience over 5 years (Females and males with work experience more than 5 years: 33 Radiotherapy technologists, 14 Nuclear medicine technologists and 46 Nurses).

Results showed that even radiation exposed groups with work experience over 5 years had significant difference in hair thickness compared to control group, while hair root, hair nutrition, hair status and hair oil in three groups showed no significant difference as shown in Table 4.

Table-4: The comparison of mean of measured variables in three occupational groups with different work experiences.

	Nurse $\bar{X}$ ±SD	Nuclear medicine $\bar{X}$ ±SD	Radiotherapy $\bar{X}$ ±SD	P-Value
Personnel with work experience over 5 years				
hair thickness (µm)	74.21±12.21	63.28±8.36	67.68±11.36	< 0.01
Hair root	2.78±1.26	2.92±1.32	2.66±1.33	0.81
Hair Nutrition	1.50±0.83	1.64±0.92	1.72±0.94	0.52
Hair Status	1.60±0.74	1.57±0.93	1.66±0.77	0.91
Hair oil	2.52±0.86	2.50±1.01	2.69±0.72	0.61
Personnel with work experience under 5 years				
hair thickness (µm)	71.81±10.8	73.33±9.71	70.91±10.03	0.86
Hair root	2.30±1.39	2.66±1.32	2.13±1.30	0.64
Hair Nutrition	1.54±0.85	1.44±0.72	1.73±0.96	0.68
Hair Status	1.60±0.81	1.77±1.30	1.73±0.70	0.80
Hair oil	2.37±0.94	2.11±1.05	2.06±1.03	0.81

For personnel with work experience under 5 years there was no significant difference in hair thickness, hair nutrition, hair status and hair oil in the three groups as mentioned in Table 4 (Females and males with work experience less than 5 years: 15 radiotherapy technologists, 9 Nuclear medicine technologists and 35 Nurses). The Tes-TB device showed significant difference in hair thickness between female radiation exposed groups and female control group. Although radiation exposed groups received a little dose in every session, their hair was damaged. Furthermore, although radiation exposed groups received a little dose, their whole bodies absorbed dose. Therefore, there is possibility of damage in each tissue (16). Previous studies showed cell cycle delay in single irradiation [12]. Cell cycle delay caused the accumulation of cells at the checkpoints G1 / S and G2 / M. This delay due to the dose rate is different in various studies [7, 17, 18]. It was not found any study about chronic exposure effect on hair cell cycle delay. Maybe it is not clear if checkpoints could be active because of chronic exposure.

Discussion

The aim of this study was to investigate the radiation- induced damages on hair of radiation exposed groups. It was expected that by using this device dramatic changes caused by irradiation in hair could be determined, yet the Tes-TB showed that the radiation- induced damages on hair were not very intense. However, the results of this study only confirmed a part of our hypotheses. Most of the previous studies investigated the acute radiation effects on hair and

showed that the minimum dose for hair cell death is 50cGy (7, 17). However, this study focused on chronic exposure effects on hair. The value of absorbed dose by radiation exposed groups in each exposure is about 2cGy or more (18 and 19). So, further investigations are required in this field to confirm this hypothesis. The results are particularly interesting for developing countries especially Iran because radiation exposed groups of these countries are not trained properly to protect them against radiation. Moreover, their working hours are exceeded. Although a validated questionnaire with face validity and content validity approved by some professional experts was administered and also the Tes-TB device with high accuracy for measuring hair parameters was used, yet there may be other ways which can be used to measure hair damages more easily and accurately.

Conclusion: Results of the study showed that chronic exposure may cause damage to the hair of radiation workers. The reason may be inadequate training of technologists and their high workload.

Acknowledgments: We thank SHEPCO. Biomedical Engineering Co, agency of KC Technology Company that let us use Tes-TB device for this study. This study was supported by Cancer Research Center.

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