Radiation Therapy Effects on Human Hair

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Abstract

Radiation therapy is painless, powerful, and people who receive it might have some problems during and after treatment. These problems are different from person to person. For example, some people who have radiation therapy may feel more tired than usual, not feel hungry, and lose their hair. The aim of this research is to study the radiation effects on human hair. Hair samples were collected from the cancer patients at Radiation Oncology of Yangon General Hospital. The hair was cut before giving radiation to the patients. Each patient was given the same Gamma radiation dose of 4500 (CGy) on different parts of the body. The elemental concentrations of hair from cancer patients were determined by using EDXRF Method. It was found out that the concentrations of main elements (S, Fe, Ni) decrease and other elements (Pb, Zn, Ca) change due to radiation on the body.

Keywords: Radiation Therapy elemental concentration, Gamma radiation

Introduction

Hair Structure and Hair Life Cycle

Hair is composed of strong structure protein called keratin. This is the same kind of protein that makes up the nails and the outer layer of skin. Hair is made of two parts, the shaft and the root ,which is under the scalp.The part of the hair seen above the skin is called the hair shaft. The hair shaft is made up of dead cells that have turned into keratin and binding material, together with small amount of water. This structure explains why it does not feel any pain while the hair is being out. The hair shaft is formed by three layers. The innermost layer of the hair shaft is named the medulla. It is seen only in large and thick hairs. The middle layer of the hair shaft is called the cortex, made of keratin fibers. The strength, color and texture of a hair fiber are provided by the cortex layer of the hair shaft. The outermost layer of the hair shaft is the cuticle. This thin and colorless layer made up of between six to ten overlapping layers of long cell remnants, serves as a protection to the cortex.

Each strand of hair consists of three layers:

1). An innermost layer or medulla which is only present in large thick hairs

2). The middle layer or the cortex. Which provides strength and both the color and the texture of hair

3). The outermost layer or the cuticle. Which is thin and colorless serves as a protector of the cortex

Below the surface of the skin is the hair root, which is enclosed within a hair follicle. At the base of the hair follicle is the dermal papilla. The dermal papilla is fed by the bloodstream which carries nourishment to produce new hair. The dermal papilla is a very important structure for hair growth because it contains receptors for male hormones and androgens. Androgens regulate hair growth and in scalp hair. Androgens may cause the hair follicle to get progressively smaller and to become finer in individuals who are genetically predisposed to this type of hair loss. Hair follicles grow in repeated cycles. One cycle can be broken into three phases. They are

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1). Anagen - Growth Phase

2). Catagen - Transitional Phase

3). Telogen - Resting Phase

Each hair passes through the phases independent of the neighboring hairs.

Approximately 85% of all hairs are in the growing phase at any time. The Anagen phase or growth phase can vary from two to six years. Hair grows approximately 10 cm per year and any individual hair is unlikely to grow more than one meter long.At the end of the Anagen phase the hair enters into a Catagen phase which lasts about one or two weeks, during the Catagen phase the hair follicle shrinks to about 1/6 of the normal length. The lower part is destroyed and the dermal papilla breaks away to rest below.

The resting phase follows the Catagen phase and normally lasts about 5-6 weeks. During this time the hair does not grow but stays attached to the follicle while the dermal papilla stays in a resting phase below. Approximately 10-15 percent of all hairs are in this phase at one time. At the end of the Telogen phase the hair follicle re-enters the Anagen phase. The dermal papilla and the base of the follicle join together again and a new hair begins to form. If the old hair has not already been shed, the new hair pushes the old one out and the growth cycle starts all over again.

Chemical Composition of Hair

Though there are different chemical components present in the human hair, it is an “integrated” system. The different chemical components in human hair act together to maintain the normal flow of functions. Some of the important structural and functional chemical components and their significance for hair are presented protein, water, hair lipids and hair pigments. Protein is the most important element and is present throughout the hair from root to tip. Hair, from its growth under the skin of the scalp, is filled with a fibrous protein called keratin. Most of the keratinous proteins are present within the cortical cells, but significant and important proteins are also present in the medulla of hair fibers but they are probably of little physicochemical significance. The protein of hair is made up of long chains of amino acids. The amino acids are joined to each other by chemical bonds called peptide bonds or end bonds. The joining of these small peptide bonds produces long chains of amino acids which are called polypeptide chains. The keratin protein found in hair is called “hard” keratin.

Elements of Hair

Hair is made of protein which originates in the hair follicles. As the cells nature, they fill up with a fibrous protein called keratin. These cells lose their nucleus and die as they travel up the hair follicle. Approximately 91 percent of the hair protein is made up of long chains of amino acids. The amino acids are joined to each other by chemical bonds called peptide bonds or end bonds. The long chain of amino acids is called a polypeptide chain and is linked by peptide bonds. The polypeptide chains are intertwined around each other in a helix shape. There are various elements found in the hair and they are used to make amino acids, keratin, melanin, and protein. The average composting of normal hair is composed of 45.2% carbon, 27.9% oxygen, 6.6% hydrogen, 15.1% nitrogen and 5.2% sulphur[(4)]. The keratin found in hair is called “hard” keratin. This type of keratin does not dissolve in water and is quite resilient.

Radiation Exposure and Cancer Treatment

Radiation is the emission (sending out) of energy from any source. The light that comes from the sun is a source of radiation, and it is the heat that is constantly coming off our bodies. When talking about radiation, however, most people think of specific kinds of radiation produced by radioactive materials or nuclear reactions. Most forms of radiation have not been linked to cancer. Only high frequency radiation (ionizing radiation and ultraviolet radiation) has been proven to cause genetic damage, which can lead to cancer. The hazards of exposure to some kinds of radiation were recognized shortly after the discovery of the X-ray in 1895. Skin reactions were observed in many people working with early X-ray generators, and by 1902 the first radiation-caused cancer was reported in a skin sore. Within a few years, a large number of such skin cancers had been observed. The first report of leukemia (a cancer of the bone marrow) radiation workers appeared in 1911. Marie Curie, the discoverer of radium, and her daughter believed that radiation caused leukemia. Since that time, many studies have confirmed the cancer-causing effects of some types of radiation.

Ionizing Radiation

Radiation can generally be defined as being ionizing or non-ionizing. Ionizing radiation consists of high-energy waves that are able to penetrate cells and can cause ionization in different parts of the cell. Ionization is the development of a positive charge in a molecule that is normally neutral. Ionized molecules are unstable and quickly undergo chemical changes. This can lead to the formation of tree radicals facts that can damage the molecule or other molecules around it. One type of molecule that is sensitive to ionizing radiation is DNA, the part of the cell that contains the genes (blueprints) for each person's characteristics ionizing radiation, can lead to a mutation (change) in a cell's DNA which could contribute to cancer, or to the death of the cell. All cells in the body can be damaged by ionizing radiation. The amount of damage is related to the dose of radiation received by the cell. While the process of cellular change from radiation takes only a fraction of a second, other changes such as the beginning of cancer may take years to develop.

Types of ionizing radiation include X-rays, gamma rays, cosmic rays, and particle given off by radioactive materials such as alpha particles, beta rays, and protons. The forms of radiation have different energy levels and can penetrate cells to different extents, but all are capable of causing ionization.

People may be exposed to 3 main types of ionizing radiation:

- **Natural background radiation** comes from cosmic rays from our solar system and radioactive elements normally present in the soil. This is the major contributor to worldwide radiation exposure.
- **Non-medical synthetic radiation** occurs as a result of above ground nuclear weapons testing that took place before 1962 as well as occupational and commercial sources.
- **Medical radiation** comes in the form of diagnostic X-rays, as well as radiation therapy. Radiation therapy is currently used to treat some types of cancer and involves dosages many thousand times higher than those used in diagnostic X-rays.

Radiation therapy

Radiation is special kind of energy carried by waves or a stream of particles. It can come from special machines or from radioactive substances. When radiation is used at high doses (many times those used for x-ray exams), it can be used to treat cancer and other illnesses. Special equipment is aimed to use the radiation at tumors or areas of the body where there is disease. The use of high energy rays or particles to treat disease is called radiation therapy. Sometimes it's called radiotherapy, X-ray therapy, cobalt therapy, electron beam therapy, or irradiation. Radiation therapy (also called radiotherapy, X-ray therapy, or irradiation) is the use of a certain type of energy (called ionizing radiation) to kill cancer cells and shrink tumors. Radiation therapy injures or destroys cells in the area being treated (the "target tissue") by damaging their genetic material, making it impossible for these cells to continue to grow and divide. Although radiation damages both cancer cells and normal cells, most normal cells can recover from the effects of radiation and function property. The goal of radiation therapy is to damage as many cancer cells as possible, while limiting harm to nearby healthy tissue. Radiation therapy may be used to treat almost every type of solid tumor, including cancers of the brain, breast, cervix, larynx, lung, pancreas, prostate, skin, spine, stomach, uterus, or soft tissue sarcomas. Radiation can also be used to treat leukemia and lymphoma (cancers of the blood-forming cells and lymphatic system respectively). Radiation dose to each depends on a number of factors, including the type of cancer and whether there are tissues and organs nearby that may be damaged by radiation.

Radiation therapy can be in either of two forms: external on internal. Some patients have both forms, one after another. Most people who receive radiation therapy for cancer have the external type. It is usually given during outpatient visits to a hospital or treatment center. In external therapy, a machine directs the high-energy rays or particles at the cancer and the normal tissue surrounding it. One type of machine that is used for radiation works in slightly different ways. Some are better for treating cancers near the skin surface; others work best on cancers deeper in the body. When internal radiation therapy is used, a radioactive substance, or source, is sealed in small containers such as thin wires or tubes called implants. The implant is placed directly into a tumor or inserted into a body cavity. Sometimes, after a tumor has been removed by surgery, implants are put into the area around the incision to kill any tumor cells that may remain. Another type of internal radiation therapy uses unsealed radioactive sources. The source is either taken by mouth or is injected into the body.

The amount of radiation absorbed by the tissues is called the radiation dose (or dosage). Before 1985, dose was measured in a unit called a "rad" (radiation absorbed dose). Now the unit is called a gray (abbreviated as Gy). One Gy is equal to 100 rads; one centigray (abbreviated as cGy) is the same as 1 rad. Dose energy imparted to matter by nuclear transformations (radioactivity).

(a) Rad =100 ergs per gram.

1 GRAY=100 rad=10,000 ergs per gram.

(b) Rem= rads x Q

Where Q is a quality factor which attempts to convert rads from different types of radioactivity into a common scale of biological damage.

Health Effects of Radiation

Health effects of radiation are divided into two categories: threshold effects and non-threshold effects. Threshold effects appear after a certain level of radiation exposure is reached and enough cells have been damaged to make the effect apparent. Non-threshold effects can occur at lower levels of radiation exposure. Threshold effects occur when levels of radiation exposure are tens, hundreds, or thousands of times higher than background, and usually when the exposure is over short time, such as a few minutes. Some examples of observed threshold effects and the doses which cause them are presented in Table (1). Dose is measured in rem or millirem (1,000 millirem=1 rem).

Table (1) Threshold Effects

Dose (in rem)	Effects
5 to 20	Possible latent effects(cancer), possible chromosomal aberrations
25 to 100	Blood changes
More than 50	Temporary sterility in males
100	Double the normal incidents of genetic defects
100 to 200	Vomiting, diarrhea, reduction in infection resistance, possible bone growth retardation in children
200 to 300	Serious radiation sickness, nausea
More than 300	Permanent Sterility in females
300 to 400	Bone marrow and intestine destruction
400 to 1000	Acute illness and early death (usually within days)

It can occur at any level of radiation exposure, but the risk of harmful health effects generally increases with the amount of radiation absorbed. The most studied non-threshold effect is cancer. (1) not all cancers are caused by radiation, (2) exposure to a particular dose may cause cancer in one person but not another, and (3) the cancer often doesn't appear until many years after the exposure by other carcinogens in the environment.

Method of Analysis

X-ray Fluorescence Spectroscope

When a primary X-ray excitation source from an X-ray tube or a radioactive source strikes a sample, the X-ray can either be absorbed by the atom or scattered through the materials. The process in which an X-ray is absorbed by the atom by transferring all of its energy to an innermost electron is called the "photoelectric effect'. During this process if the primary X-ray has sufficient energy, electrons are ejected from the inner shells, creating vacancies. These vacancies present an unstable condition for the atom. As the atom returns to its stable condition for the outer shells are transferred to the inner shells, the process gives off a characteristic X-ray whose energy is the difference between the two binding energies of the corresponding shells. Because each element has a unique set of energy levels, each element produces X-ray at a unique set of energies, allowing one to non-destructively measure the element composition of a sample. The process of emission of characteristic X-ray is called "X-ray Fluorescence Spectroscopy".

Experimental Procedure

Sample Collection

Hair samples were collected from five cancer patients from Radiation Oncology of Yangon General Hospital. First, their hair was cut (3 cm-5 cm) closely head scalp before radiation. Then their hair was cut second time after being given from total radiation (4500 CGy).

Table (2) The hair sample of five cancer patients (before and after radiation)

	Sample(1)	Sample(2)	Sample(3)	Sample(4)	Sample(5)
Name	Daw Aye Win	Daw Aye Aye Win	Daw Yin Nwe	Daw May Yie	DawMyaThwin
Age	45 Years	26 Years	67 Years	65 Years	61 Years
Weight	130 lb	125 lb	126 lb	121 lb	124 lb
Disease	Ca-breast	neck gland front investigation	Ca-breast	Ca-breast	Brain Tumour
Treatment	daily treatment	daily treatment	daily treatment	daily treatment	daily treatment
Dose	225 CGy/day (1 day) 4500 CGy/ R (20 days)	200 CGy/ day (1 day) 5000 CGy/ R (25 days)	225 CGy/ day (1 day) 4500 CGy/ R (20 days)	225 CGy/day (1 day) 4500 CGy/R (20 days)	225 CGy/ day (1 day) 4000 CGy/ R (20 days)
Field size	15 cm × 17 cm	10 cm × 12 cm	10 cm × 15	10 cm × 12 cm	15 cm × 15 cm
Distance	100 cm	100 cm	100 cm	100 cm	100 cm
Everyday meal	Meat (more) Fish (more) Vegetable (little)	Meat (little) Fish (little) Vegetable (more)	Meat (more) Fish (more) Vegetable (more)	Meat (no) Fish (little) Vegetable (more)	Meat (more) Fish (little) Vegetable (no) Cooffe (over)

Sample preparation for measurement using EDXRF method

All the hair samples were made into fine powder. Then the sample from each patient was pressed into pellet with 2.5 cm in diameter and thickness 1 cm. The EDXRF machine (EDX-700) was used for determining the concentrations of elements in dried hair samples. The machine can provide the information of elements from silicon to Uranium (Si-U).

Results of EDXRF Analysis

In this study, hair samples of the five cancer patients were analyzed using EDXRF technique by EDX-700 spectrometer. The experimental work was performed at Universities' Research Centre, Yangon University. The concentrations of elements contained in these samples were shown in Table(3) and figures (1, 2, 3, 4 and 5).

Table (3) The elemental concentrations of hair before and after giving radiation by EDXRF method

Sample	Radiation	S	Pb	Zn	Fe	Ca	Cu	Ni
(1)	Before	100	-	-	-	-	-	-
	After	87.812	10.633	1.524	-	-	-	-
(2)	Before	100	-	-	-	-	-	-
	After	51.142	-	22.433	26.426	-	-	-
(3)	Before	100	-	-	-	-	-	-
	After	75.338	-	5.242	4.988	14.432	-	-
(4)	Before	-	-	-	100	-	-	-
	After	44.113	-	-	55.887	-	-	-
(5)	Before	-	-	-	14.958	-	42.718	60.544
	After	-	-	-	12.353	-	24.499	44.929

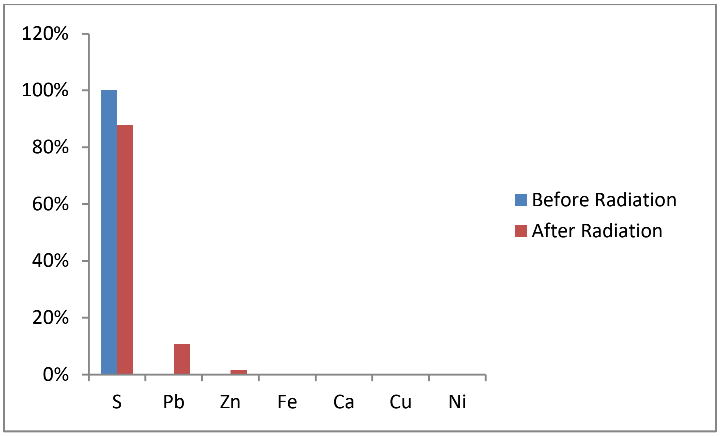

Figure (1) The elemental in hair sample (1) of patient before and after radiation.

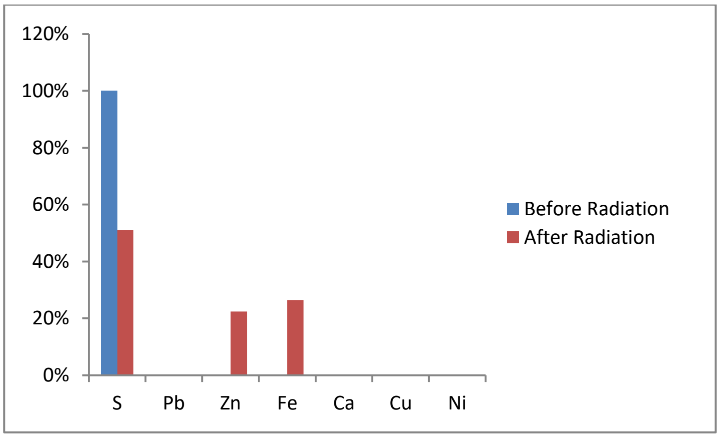

Figure (2) The elemental in hair sample (2) of patient before and after radiation.

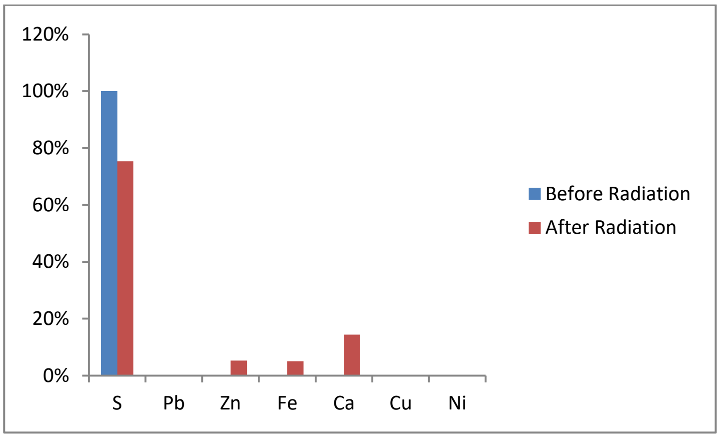

Figure (3) The elemental in hair sample (3) of patient before and after radiation.

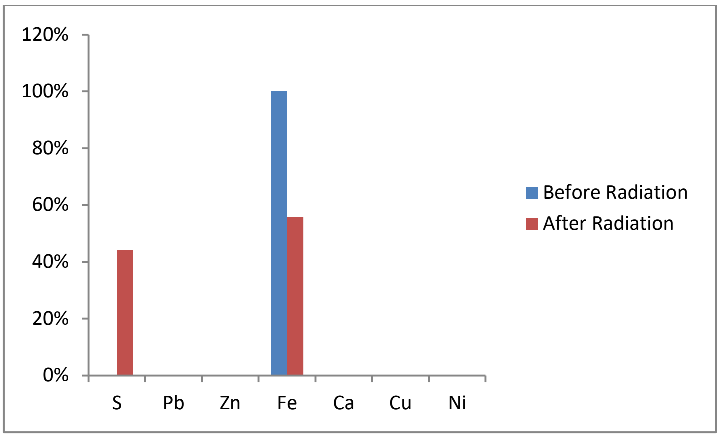

Figure (4) The elemental in hair sample (4) of patient before and after radiation.

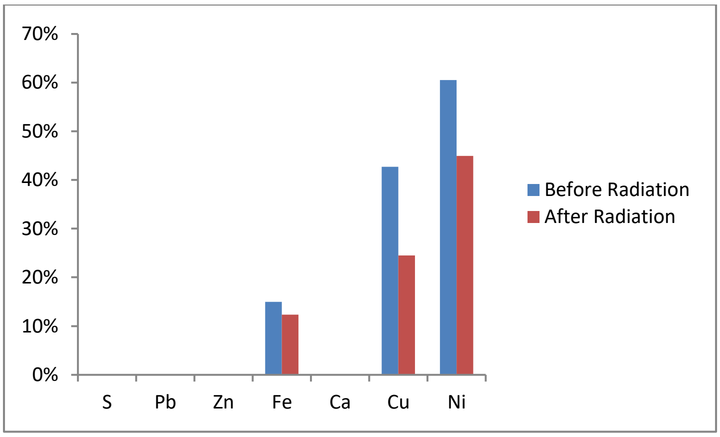

Figure (5) The elemental in hair sample (5) of patient before and after radiation.

Results and Discussion

When a cell absorbs radiation, there are four possible effects on the cell. Firstly, the cell may suffer enough damage that can cause loss of proper function and the cell will die. Secondly, the cell may lose its ability to reproduce. Thirdly, the cells can be damaged so that future copies of the cell are altered. Finally, the absorption of radiation by a cell may have no adverse effect. In this work, radiation effect on hair was studied. Hair is made up of two parts: the shaft, and the root which is under the scalp. Hair growth occurs at the root. Radiations go through the blood to many places, including the hair root. The radiation can block the growth of these root cells, making hair weak and causing it to fall out. Because the growth and rest pattern of hair varies, hair thinning may not occur evenly over scalp. Radiation disrupts hair growth in the same way. Hair samples from cancer patients and irradiated hair were studied to determine the elemental concentrations in them. The EDXRF technique is a multi-elemental quantitative determination and it can provide concentrations of many elements contained in the sample by single experiment.

Conclusion

The X-ray fluorescence method has been found to be a suitable technique for multi element analysis of hair samples from cancer patients. The hair was cut before and after irradiation. The elemental concentrations of (S, Fe, Ni) in hair samples were decreased and the other elements (Pb, Zn, Ca) were changed by radiation effect. The loss of element concentrations did not depend on the patient's body, age and weight but it depended on radiation doses. It was also found that there was a great effect on element contents in scalp hair due to radiation exposed on different parts of the body. Thus, the scalp hair became to lose and fall out. When nuclides were resent on the surface of the skin, relatively large doses, may be delivered in a short period of time. Radiation went through the blood to many places, including the hair root. The radiation could block the growth of these root cells, making the hair weak and causing it to fall out.

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