A Report on "Radiation Disaster Recovery Studies"

Course: Radiation Disaster Medicine
Name: Chryzel Angelica B. Gonzales

○ Regarding "Radiation Disaster Recovery Studies"

The use of radiation in medicine and industry, as well as an energy source (i.e., nuclear power) remains widely increasing in the last decades. Although the proper use of radiation is undoubtedly beneficial in this modern technology society, chances of radiation accidents or potential terrorist-related threats are also a concern in the recent years. Given that radiation disaster is a very complicated event generating much public fear, potential human health risks, and environment effects; hence, our world needs future global leaders who are adequately trained in radiation disaster recovery with a strong sense of responsibility and commitment.

I am extremely fortunate to be part of the Phoenix Leader Education Program (PLEP) which aims to foster such global leaders in response to radiation disasters. My experience in the PLEP not only imparted knowledge in radiation emergency preparedness and response, but also the importance of interdisciplinary approach in a radiation disaster recovery. For instance, persons from different disciplines are needed and cooperation among different experts is vital to ensure recovery from the disaster. And since the PLEP is designed to prepare future experts in post-radiation disaster recovery, students from different countries with different academic backgrounds were able to work as team members through numerous excellent technical trainings, fieldworks, and educational seminars. Although, it is expected that one is a leader in his/her own right and in a close environment such as this program where the students are together most of the time, sometimes conflicts could arise from simple misunderstandings due to differences in areas of specialization, in age groups, or even in professional ranks, which can result to ineffective communication. Thus, I must say that good communication and social skills and showing respect for work, people, and community are among the best strategies in reaching goals of outstanding leadership in recovery efforts.

In my 4 years of study in the program, apart from being educated to be highly skilled leaders in radiation safety and response, we are also trained as good communicators who must express ourselves clearly with confidence. Recovery from radiation disaster also requires leaders who have the ability to build consensus by conveying accurate information to other professionals and various publics and stakeholders. With this, as a product of PLEP, I learned the significance of giving useful, timely, truthful, consistent, and appropriate messages to avoid harmful misinformation. But communication involves not just talking but also listening, a key and often forgotten component of effective communication. While there are various ways to exercise effective communication, the goal of communication is to hear not only facts but also feelings; one must exhibit openness and awareness in order to construct an effective and reliable support system to the disaster victims.

The PLEP also honed us to be leaders playing an active role in regional and global society through the collaborating system with domestic and international universities, research institutes, international organizations, and corporations. Through this , I did not only obtain on-site practical skills and advanced knowledge in radiation disaster medicine, but I also learned the importance of having a global attitude that the focus of concern moves beyond local issues found within the boundaries of space, time or community, to global issues that cut across local or national boundaries. Further, a leader with a global attitude also involves moving beyond being exclusively concerned with the present, and connects the present to the past, and the present to the future. Because radiation disasters oftentimes transcend borders in the form of environmental contamination involving the presence of long-lived radionuclides, and thus concern for the future generation is absolutely important.

The world has become so strongly interconnected that one cannot ignore the fact that a major event happening in one part of the world has a global impact, especially that of a radiation disaster which cannot be handled using a simple and one-dimensional approach. Hence, one must perceive his/herself as connected to the world of community. Being honest, the journey towards getting a Ph.D. degree is not easy; in fact, it has tons of challenges. However, I am truly obliged to be part of the PLEP as the opportunities offered are no comparable to any other programs. Very few things in life are entirely the work of one person – and this is no exception, so I am deeply grateful to all my colleagues, professors, and the staff of the PLEP for the fruitful learning experience and their enormous contributions to connect research and science with radiation disaster recovery.

○ Title of Doctoral Thesis

Investigation of the applicability of the ESR nail dosimetry for assessment of accidental exposure in medical facilities

○ Summary of Doctoral Thesis

INTRODUCTION

Recent technologies in the field of radiotherapy and diagnosis accompanied by the complexity of calibration of new equipment, treatment-planning techniques, and delivery systems have a great potential of unexpected errors that may lead to accidental exposures to patients and medical staff. In the last decades, a considerable increase in the number of severe accidents in radiotherapy with regard to patient exposures has been reported. In addition, the risk of high-dose exposure to the operator and medical staff in fluoroscopically guided interventional procedures has long been recognized as one of the most important issues in the field of radiological protection. Apart from this, the radiation hand exposure of the medical staff handling radiopharmaceuticals is also a concern, although this remains unclear at present. Hence, the extant reported accidental exposures then make clear the fundamental importance to immediately employ a practical method for retrospective dosimetry that could provide a precise dose assessment in a short period of time after a radiological accident. This is particularly essential, in most cases for patients, because they are very unlikely to be equipped with radiation monitoring devices during treatment and diagnosis procedures and for medical staff who are not adequately trained radiation workers. Further, it could also provide benefits in some other significant areas of concern such as terrorist-related events involving the dispersal of radioactive nuclides, radiation source handling, and nuclear power plant accidents. Accordingly, the present study focused on the retrospective dosimetry technique based on the electron spin resonance (ESR) analysis of radiation-induced radicals in solid biological samples resulting from reactions in matter generated by ionizing radiation. Accordingly, fingernails have been considered a favorably attractive tissue material for dosimetric purposes due to its facile sample collection. In this study, we report the applicability of fingernails as a retrospective dosimeter in radiological accidents, and some modified techniques are introduced to improve the ESR signal stability of the fingernail samples.

MATERIALS AND METHODS

Fingernails investigated in this study were collected from three healthy donors during routine hygienic procedures. Two experiments were set up to study the fingernails ESR signals with two different preparations: water-treated and untreated. Sample treatment was performed by 1-hr soaking to distilled water followed by 1-hr drying inside a heat dryer sterilizer with the heating temperature set to 100°C. This treatment was done to remove all the possible unknown signals, for example, dirt or any physical factors and cutting effects that can play a significant contribution to the mechanic-induced signal (MIS) and background signal (BKG). In addition, the stability of the ESR signals was tested under two different

drying conditions with drying time set to 1-hr: vacuum desiccator at 20°C temperature and heat dryer sterilizer at 100°C temperature. While, untreated samples were given no additional special treatment.

The radiation-induced signal (RIS) was obtained after the irradiation of fingernails to 35 Gy and 70 Gy with a clinical linear accelerator (LINAC) at Hiroshima University Hospital. High-dose levels were employed to simulate accidental exposures using a high-energy 6-MV photon beam. The ESR measurements were performed on a JES FA 100 spectrometer. Quantitative analysis of the spectra, which included baseline corrections and measurement of the peak-to-peak amplitude of ESR signal intensities, was carried out using the A-system data processing software. Samples were measured at different elapsed times after irradiation and always kept inside the vacuum desiccator with humidity levels in the range of 30–40% at 20°C room temperature in between multiple measurements.

RESULTS AND DISCUSSION

a. *Stability of BKG*

Experimental results revealed that the samples dried in the vacuum desiccator exhibited signal instability for the initial 10 days and became stable after 20 days. Moreover, ESR response obtained from samples dried inside the heat dryer sterilizer with 100°C temperature showed a good stability of the ESR signal up to 30 days of postmeasurement. Although the ESR spectra for samples dried using a heat dryer sterilizer are also more substantial than those in the vacuum dried samples, which might be due to the influence of the drying temperature, the signal stability is critically important for BKG corrections. However, one can also say that the degree of response for samples dried at 100°C may be related to the denaturation of some original properties of fingernail tissues.

Additional experiment to test the stability of the BKG signal indicated a very similar behavior of for both vacuum-stored treated and untreated samples. The BKG signals were also seen to slightly increase within 24 hours and proximately reached a stabilization state with very minimal fluctuations up to 39 days of postmeasurement. Therefore, it is firmly believed that the unirradiated samples kept under vacuum storage condition resulted in good stability of the BKG signal. Further, vacuum-stored water-treated and untreated samples exhibited similar initial increase of the BKG signal, which affirmed that some factors such as humidity, temperature, and ambient light, among others, are responsible for the signal growth. Another experiment with some setup modifications (i.e., use of black sheets) was conducted in order to examine the effect of ambient light to the BKG signal during sample drying, storage, and spectral measurements. Results indicated that the BKG intensity did not exhibit any prompt signal growth in the first few hours of measurements and remained relatively stable up to 39 days. From this experiment, one can further say that if we reduce the exposure of the fingernail samples to ambient light, we can achieve a more stable BKG signal which is an important factor in the fingernail analysis.

b. *Stability of RIS*

According to the results, there are two observed contributing signals namely, RIS-singlet and RIS doublet. However, the spectra obtained from the vacuum-stored samples irradiated to 70 Gy mainly consisted of RIS-singlet. The observed signal intensity increased in the first few hours after irradiation and continued to increase until several days of postirradation. Moreover, it was suggested that the response of the samples with limited ambient light exposure from the three donors at 35 Gy is comparable to one another, while considerable differences can be seen between curves at 70 Gy with ambient light exposure. It was suggested that the observed dynamics illustrate the effectiveness of inhibiting the exposure of samples from ambient light exposure. One important observation is that the RIS-singlet obtained from both samples is quite stable under vacuum storage condition. Another interesting observation is that the time to reach the maximum peak of the signal, perhaps before the fading occurred and gradually remained constant, exhibited a quite different behavior among the three donors. Therefore, it has been noted that the peak-to-peak intensity of the RIS-singlet could be just an effect of the overlapping of stable RIS-singlet with unstable RIS-doublet. At the same time, it is surmised that the observed diverse fading patterns are attributable to the varying amounts of keratin, which play an important role in keeping the trapped unpaired electrons produced by ionizing radiation.

In an attempt to further understand the influence of the water-treatment on the irradiated samples, samples were collected again from the same individuals and exposed to 70 Gy without any additional special treatment. Results clearly show the difference in the RIS-singlet behavior of untreated samples compared to those of water-treated samples: no such large signal increases were apparent for the untreated samples. Additionally, it is likely that the signal fading pattern of the water-treated samples is nearly the same in untreated samples where the fading occurred immediately after irradiation, but the observed rate of the RIS-singlet for the water-treated samples is much slower than for untreated samples. Drying conditions may have played some role in this phenomenon, as it has been observed that there was good signal stability for unirradiated water-treated samples, which also underwent the same drying process as the irradiated water-treated samples. Nonetheless, it is very important to clarify the role of the drying conditions (i.e., heating temperature and time) to fully understand its effect on the ESR signals of fingernails.

c. Dose-response

The dose–response curves of the vacuum-stored samples obtained from the three different donors were found to be linear in the dose range of 0–70 Gy, which covers the vast majority of accidental overexposure doses in radiotherapy, with R^2 values equal to 0.99. Another interesting observation is that the dose–response curves were distinct among the donors. This then entails that further investigations are needed to comprehensively attest the variability of age and gender, among others.

CONCLUSION

The stability of the ESR signals (particularly BKG and RIS) has been studied in fingernail samples collected from three different individuals. The effects of drying conditions, sample preparations, and setup modifications were examined and compared among the three individuals. The results obtained in the present study suggest that fingernails could be useful for assessing retrospective dosimetry after an unexpected accidental exposure, provided that the uncertainties related to the variable behaviors (e.g., fading patterns, dose–response, etc.) of the ESR signals from individual fingernails would be sufficiently reduced. Further studies to correct such uncertainties in relation to both physical condition and physiological factors are indispensable for practical applications of ESR nail dosimetry method.

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○ Other theses published in academic research journals

1. CAB Gonzales, H Yasuda, S Hirota, K Miki, A Saito, JE Taño, and Y Nagata: Fingernail dosimetry using electron spin resonance for radiation disaster response. *IOP Conf. Series: Journal of Physics: Conf. Series* (in press).
2. JE Taño, S Hayashi, S Hirota, CAB Gonzales, and H Yasuda: Development of a reusable PVA-GTA-I gel dosimeter for 3D radiation dose assessments. *IOP Conf. Series: Journal of Physics: Conf. Series* (in press).