Study on Influence of X-ray Baggage Scan on ESR Dosimetry for SNTS using Human Tooth Enamel

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The influence of X-ray baggage scanning on electron spin resonance (ESR) dosimetry studies around the Semipalatinsk Nuclear Test Site (SNTS) has been examined at Incheon Airport in Korea, which is a transfer point of the routes from Kazakhstan to Japan. Utilized dosimeters are Japanese human tooth enamel for ESR and glass dosimeters.

The difference between the estimated doses with the X-ray scan and those without it is below the evaluation errors for both ESR and the glass dosimeters. For glass dosimeters, the dose from the X-ray scan is estimated to be lower than the detection limit for the utilized glass dosimeters of ten µGy. This supports the absence of significant difference for the ESR results, which have an error in the order of ten mGy. Since ESR dosimetry for SNTS usually has similar errors, the dose by the X-ray scan in this study is concluded to be negligible in ESR dosimetry using tooth enamel from residents near SNTS.

INTRODUCTION

In the Semipalatinsk Nuclear Test Site (SNTS) in the Republic of Kazakhstan, 459 nuclear test explosions were conducted from 1948 until 1989. SNTS and its vicinity were contaminated with the radioactive fallout during this period. There have been many attempts to estimate radiation doses for the local population residing there.1–7) Among them, electron spin resonance (ESR) spectroscopy of tooth enamel is a method to evaluate radiation doses in uncontrolled and accidental situations.8,9) ESR is sensitive to low doses down to several tens mGy and this aspect is important for ecological monitoring and personal dose estimation in radiation contaminated territories. ESR has been validated through dose estimations in radiation accidents10) and the atomic bomb survivors11) and has been applied to the SNTS dosimetry.5,6)

Before the ESR measurement, local people’s teeth are brought to the laboratory where the ESR spectrometer is installed. Assuming that the measurement is performed outside Kazakhstan, the practical way is to carry the teeth by airplane. In this process, the teeth are usually examined using X-ray baggage scanners at airports. The dose by the X-ray baggage scan is generally estimated to be from a few µGy to several tens µGy, while the dose for residents near SNTS is evaluated to be mainly in the order of ten or hundred mGy by ESR,5,6) if detected. Although X-ray baggage scan is not expected to be influential on the ESR dosimetry for SNTS, the present study aims at experimental verification of this hypothesis.

MATERIALS AND METHODS

The influence of the X-ray baggage scan was investigated by comparing the dosimetry results which include X-ray scan to those without it. The utilized dosimeters are human tooth enamel and glass dosimeters.

Assuming ESR measurements in Japan, the X-ray scan was conducted in Incheon Airport in Seoul, Korea, which is a transfer point of the routes from Kazakhstan to Japan. All the dosimeters were prepared in Japan. Two wisdom teeth named ‘A’ and ‘B’ from Japanese people were used for the ESR measurement. They were crushed into grains 0.1 mm to 0.5 mm in diameter, and separated into six samples, i.e., two for the buccal side of the tooth ‘A’, two for the lingual...
side of ‘A’, and two for whole ‘B’. Moreover, ten glass dosimeters (Asahi Techno Glass Corporation, SC-1) were prepared.

They were carried to Incheon Airport for an X-ray scan and brought back to the Research Institute for Radiation Biology and Medicine (RIRBM), Hiroshima University in Japan for measurements. They were kept in pockets of a jacket worn by a person all the way in order to simulate realistic transport of tooth samples. For scanning teeth, one sample for each of tooth ‘A’ (buccal side), ‘A’ (lingual side), and ‘B’, i.e., in total three samples, were kept in a pocket of a scanned un-worn jacket. For scanning glass dosimeters, five elements were set in a box made of thin paper which is expected to be scarcely influential on the X-ray field. During the scan, the other samples and dosimeters were not scanned, but kept in a pocket of another jacket worn by the researcher.

ESR spectra were analyzed to determine the signal value using the computer code developed by A. Ivannikov et al.12 This code deconvolutes the ESR spectrum into the background signal and the radiation induced signal by a fitting procedure using the first derivative Gaussian functions. The tooth-dose is evaluated by the additive dose method. Additive dose irradiations were performed using the 60Co gamma rays source in RIRBM.

RESULTS AND DISCUSSION

The dependence of the radiation induced signal of ESR on the additive dose is shown in Figs. 1 (a), (b), and (c). The results of five measurements are plotted for each additive dose. The additive dose of zero corresponds to the data before receiving additive doses after the trip back to Japan. The absolute values of intercept on the X axis for linear regression of the plots are shown in Table 1 as the estimated dose. The exhibited error is derived from the regression analysis. Contribution to the estimated dose is given by dose due to the natural background radiation during the life of a tooth since enamel formation, by possible medical X-ray dose, and by bias dose resulting from the difference between the shape of the real native signal and the model signal used in the spectra-analyzing computer code. Since the same kinds of samples were utilized for the group with the X-ray scan and the group without it, the important value to estimate the contribution of the X-ray scan is merely the difference between the estimated doses for the two groups. The differences were computed by subtracting the dose without the X-ray scan from the dose with the X-ray scan and are also shown in Fig. 1. The differences are less than the error level. The dose by the X-ray scan conducted in this study is considered to be undetectable by ESR measurement.

The results for the glass dosimeters are shown in Table 2. The exhibited values are the average of five elements and its standard deviation. A significant difference is not observed

![Fig. 1. Dependence of radiation induced signal of ESR on additive dose](a) Tooth ‘A’ (buccal side), (b) tooth ‘A’ (lingual side), (c) whole of tooth ‘B’]
between the measurements with the X-ray scan and those without it. This supports the validity of the result for ESR measurement using tooth enamel. The detection limit of the utilized glass dosimeters is 10 μGy. Therefore, the dose by the X-ray scan in this study is estimated to be lower than 10 μGy.

The dose for residents near SNTS is evaluated to be mainly in the order of ten to hundreds of mGy with the error in the order of mGy,\(^5,60\) if detected. In contrast, the dose by the X-ray scan is not expected to be as much as mGy in spite of differences in the type of the scanner, condition and number of the scans. Therefore, the dose by the X-ray scan is considered to be negligible in ESR dosimetry using tooth enamel from residents near SNTS.

CONCLUSION

The influence of the X-ray baggage scan in Incheon Airport on ESR dosimetry was investigated. The estimated doses did not show a significant difference between the measurements with the scan and those without the scan for ESR using either tooth enamel or glass dosimeters. Therefore, the dose by the X-ray scan utilized in this study is concluded to be negligible in ESR dosimetry using tooth enamel from residents near SNTS.

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Table 1. Dose estimated by ESR using tooth enamel (mGy)

|             | With X-ray scan | Without X-ray scan | Difference* |
|-------------|-----------------|--------------------|-------------|
| Tooth ‘A’ (buccal side) | 173.6±16.3 | 185.7±16.8 | -11.9±23.4 |
| Tooth ‘A’ (lingual side) | 195.4±19.0 | 198.4±23.7 | -2.5±30.4 |
| Tooth ‘B’    | 119.1±11.9 | 105.7±11.9 | 13.6±16.9 |

* ‘Difference’ is a result of subtraction of the dose without the X-ray scan from the dose with the X-ray scan.

Table 2. Dose estimated by glass dosimeter (μGy)

|             | With X-ray scan | Without X-ray scan | Difference* |
|-------------|-----------------|--------------------|-------------|
| Teeth 'A'   | 9.8±1.4         | 8.3±0.5            | 1.5±1.5     |

* ‘Difference’ is a result of subtraction of the dose without the X-ray scan from the dose with the X-ray scan.

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