Interlaboratory Comparison of EPR Dose Reconstruction Results for Russian Nuclear Workers


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INTRODUCTION

Electron paramagnetic resonance (EPR) in human tooth enamel is a powerful tool for individual dose reconstruction. This method is based on EPR measurements of the concentration of stable (~10^7 yr.) radiation induced radicals in the mineral component of tooth enamel. In spite of the growing number of the publications devoted to this method (see, for example, [1-5]) there are still some uncertain issues regarding its performance characteristics and methodological details. there is no consensus on the best routine of sample preparation, optimal conditions of EPR spectrum recording, procedure of measuring the dose response and even the dose detection limit of EPR retrospective dosimetry in tooth enamel. Another important point is how the doses determined by EPR are related to the commonly used doses measured with individual dosimeters. As a rule, the final goal of any wide scale dose reconstruction is the determination of epidemiological risk of radiation. Therefore, in the future, this method should be standardized, and its limitations should be revealed. The only way to select the best procedure of the dose reconstruction is a blind intercomparison of the results of dose reconstruction fulfilled in the independent research groups on the same samples with known doses. All the intercomparisons performed so far dealt with samples prior irradiated in vitro [6,7]. In spite of the obvious usefulness of this study such experiments cannot give an answer to the question about the actual precision of the EPR dosimetry because they take into account only the error of EPR measurements. Neither can such studies help in interpretation of the results.

Recently an approach to the procedure of dose intercomparison, which can verify the method of EPR dose reconstruction in tooth enamel, was suggested [8]. It is based on the choice of the proper group of individuals for EPR intercomparison with known radiation pre-history. Southern Ural nuclear workers of production association Mayak give a unique opportunity to fulfill such experiments. This association is the first Russian (Soviet) industrial nuclear facility (working since 1948). Its mission was to produce fission material for nuclear weapons. In the very beginning of its operation is used a uranium-graphite reactor, half a year later a radiochemical facility was constructed for uranium and plutonium extraction from the fuel. From the first days of operation the personnel of Mayak was monitored with individual dosimeters. However, the dosimetry information thus obtained suffered a drawback: up to 1955, when an external buildup material was introduced, the dosimeters were used without a filter. Obviously, film badges without a filter can record doses from low energy radiation, which do not penetrate deeply into the body. Therefore, radiation doses of this part of the Mayak nuclear workers need to be verified itself.

SAMPLES AND EXPERIMENTAL METHODS

24 teeth from Russian nuclear workers (Mayak Production Association) with known occupational exposure records were studied in the present study. These teeth were extracted by local dentists for dental treatment unrelated to this study. Dose reconstruction was performed independently in 4 different laboratories: GSF-National Research Center for Environment and Health (Neuherberg, Germany), Institute of Biophysics (Moscow, Russia), Institute of Metal Physics (Ekaterinburg, Russia), Radiation Effects Research Foundation (Hiroshima, Japan). All measurements were done without a prior knowledge of the recorded dose (double blind intercomparison). Each tooth under the present investigation was divided into two parts, which were shared by at least two laboratories. Thus, each laboratory had 16 samples (tooth halves) under measurements and, as a result of the study, there were at least 3 doses available for each tooth donor: the official dose from the Mayak authorities and 2 doses independently determined by EPR in tooth enamel. Each group used its own experimental procedures for sample preparation and dose reconstruction. The weight of tooth enamel samples used ranged between 30 and 70 mg. IMP and IBP used the additive dose method consisting of 4-5 additional exposures to a known dose of radiation to individually calibrate the EPR dose response for each sample. This method is destructive, because the additional irradiation substantially increases the original radiation-induced signals. By contrast, GSF and RERF used a calibration curve method (average EPR response per Gy per mg of
enamel) constructed from molars of German and Japanese individuals, respectively. This scheme enabled GSF and RERF to measure the same set of samples.

ANALYSIS OF THE RESULTS OF INTERCOMPARISON

As the film badges used before 1955 were without filters, the reliability of the official radiation doses for pre-1955 nuclear workers at Mayak is questionable. Therefore, an analysis of the correlation between the results of EPR dose reconstruction and the official doses for Mayak nuclear workers who received radiation doses mainly before 1955 and for those who were exposed predominately after 1955 should be done separately. The former group of nuclear workers has official radiation doses (up to 3.28 Gy) much higher than the second one. Fig. 1 shows a correlation between the official occupational doses and the results of the EPR dose reconstructions obtained at every participating laboratory, namely, Institute of Metal Physics (A); GSF National Research Center for Environment and Health (B); Radiation Effects Research Foundation (C); and Institute of Biophysics (D). The solid line shows a full agreement between the two kinds of doses. As is seen from Fig. 1, EPR generally gave lower estimates than the film badge doses, sometimes by more than 1 Gy. It is possible that the exposure to gamma rays of low energy spectrum resulted in considerable overestimation of the radiation dose by film badges without a filter. Other possible reasons, like effects of exposure of naked film badges by neutrons and electrons, which do not induce radicals in teeth, can be also considered. The high-dosed group is also known to have demonstrated considerable occupationally-related health effects [9]. This group of Mayak nuclear workers acutely needs implementation of EPR dose reconstruction for radiation health effects studies. The observation that Mayak official doses exceed the results of EPR dose reconstruction in the high-dose range (>1 Gy) seems to be very important because the results of relative leukemia risk evaluation obtained for Mayak nuclear workers on the basis of the official doses substantially differ from those derived from the Hiroshima and Nagasaki survivors.

The second selected group of Mayak nuclear workers can be used for the purpose of validating of the method of EPR dosimetry because these workers have more reliable dosimetric information. Fig. 2 demonstrates a correlation between the official doses and results of the EPR dose reconstruction carried independently at four laboratories in the low-dose range. The solid line depicts the case of full coincidence between the two kinds of doses. The dotted line shows the results of linear regression. Institute of Metal Physics (Fig. 2A) gained the highest coefficient of correlation between the two doses, e.g. 0.81; GSF National Research Center for Environment and Health (Fig. 2B) showed R=0.75; Radiation Effects Research Foundation (Fig. 2C) has R=0.67; and Institute of Biophysics (Fig. 2D) showed lowest coefficient of correlation 0.41. In analyzing Figure 2, one should take into account two additional factors: i) the limited precision of the official dose records (about 20%) and ii) significant contributions from non-occupational exposures to the total individual doses measured by EPR but not included in the official doses. These include a number of serious radioactive waste accidents in the Urals region. The influence of all these factors should be investigated in the future for a more detailed understanding of the effects seen in this investigation.
Figure 1. High doses. Comparison of Mayak official doses recalculated in the terms of the absorbed doses in tooth enamel with results of EPR dose reconstruction performed at Institute of Metal Physics (IMP, Russia) (A); GSF National Research Center for Environment and Health (GSF, Germany) (B); Radiation Effects Research Foundation (RERF, Japan) (C); Institute of Biophysics (IBP, Russia) (D). The solid line shows a full coincidence between the two kind of doses.
Figure 2. Low doses. Comparison of Mayak official doses recalculated in the terms of the absorbed doses in
tooth enamel with results of EPR dose reconstruction performed at Institute of Metal Physics (IMP, Russia) (A); GSF National Research Center for Environment and Health (GSF, Germany) (B); Radiation Effects Research Foundation (RERF, Japan) (C); Institute of Biophysics (IBP, Russia) (D). The solid line shows a full coincidence between the two kind of doses. The dotted line shows the results of linear regression. R is correlation coefficient of the liner regression.
REFERENCES