Dosimetry without Dosimeters: Measurements of Clinically Significant Doses of Ionizing Radiation from Acts of Terrorism or Accidents Using Non-Invasive In Vivo EPR Spectroscopy of Teeth In Situ

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METHODS: The approach uses a lower frequency EPR spectrometer (1.2 GHz compared to the usual 9 GHz), which can accommodate a large object and, most importantly, does not cause unacceptable heating due to non-resonant absorption of the microwave. A resonator has been specially designed that can probe teeth in situ in the mouth, maximizing the amount of enamel that is probed, because the radiation-induced EPR signal is in the hydroxyapatite matrix of the enamel. To permit rapid and comfortable positioning of the subject, we have developed a flat magnet system that can comfortably and effectively provide the required magnetic field in the teeth in the human head. Special data gathering and data processing procedures have been developed to maximize sensitivity and provide an output useable by modestly trained personnel. The challenges for the data gathering/processing aspects include the relatively low sensitivity of lower frequency EPR and the presence of a small but significant background signal in unirradiated teeth. The components of the system have been designed to make it reasonably transportable by cart, with the total system weighing about 80 kg.

RESULTS: Extensive studies have been carried out with isolated human teeth using the spectrometer designed for using the clinical EPR system developed at Dartmouth, figure 1 summarizes pertinent results. Measurements have been made in the mouth of volunteers in which irradiated teeth have been inserted in spaces with missing teeth. The S/N within the mouth can be significantly improved with respect to the same tooth measured extra-orally, because of the reduction in noise associated with the lowered q-factor. (figure 2)

DISCUSSION: It should be emphasized that this approach is designed for the rapid triage of potentially exposed individuals into categories for which appropriate actions can be taken in regard to expected short term consequences of the exposure to ionizing radiation. In this respect this approach appears to have significant advantages over any other known approach because of its appropriate rapidity, sensitivity, and accuracy for the purpose. Individuals who receive less than 50 cGy are unlikely to have any significant short term consequences. Individuals with exposures in the range of 100-200 cGy are likely to experience significant but modest symptoms, and to have a less than 5% probability of mortality within months. At doses between 200 – 600 cGy the probability of severe symptoms and potential mortality without treatment rises to near 100%, but effective treatment is available if the situation is recognized promptly. The effectiveness of treatment at higher doses diminishes rapidly.

The current level of operation probably is sufficient for immediate use to measure clinically significant exposures with the measurements being made at Dartmouth. A complete transportable dosimetry system should be available for field testing within 12 months.

ACKNOWLEDGEMENTS: This work was supported by NIH (NIBIB) grant P41 EB002032 and the Department of Defense, MCA905-02-C-0011

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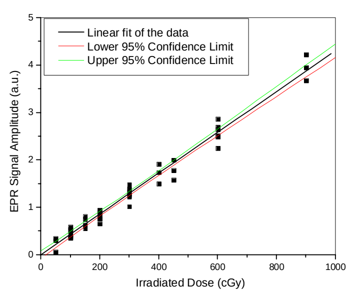

Figure 1. Dose-dependence for 15 teeth at each of 3 accumulated irradiations, standard deviation of the experimental points from linear regression SD=0.15156 a.u., R=0.98869, radiation sensitivity (slope)=0.0043±0.0001 a.u./cGy, Dose error = SD/slope=±35 cGy.

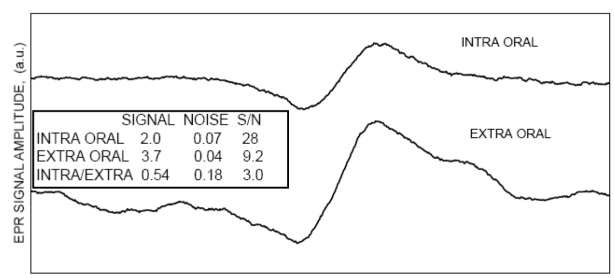

Figure 2. Spectra obtained on the same sample, in the same resonator, when placed inside the mouth of a volunteer (upper trace) versus the same sample with the resonator in air ("extra oral", lower trace). Both spectra were acquired in 4.5 minutes (averaging 90 scans) with the same settings of the EPR spectrometer. The ratio of the S/N between intra and extra oral was 3.0.