Elaborare documentație pentru fizicieni medicali

Dozimetrie EPR în radiotherapie

Dozimetria radiațiilor, protecția personalului și a pacienților este o activitate esențială a fizicienilor medicali.
Pentru dozimetria radiațiilor pot fi folosiți detectori standard sau aceasta poate fi efectuată prin măsurarea radicalilor liberi produși în diferite sisteme moleculere.

Pentru pregătirea de specialitate a fizicienilor medicali, dar și pentru identificarea unor teme actuale pentru competiția de proiecte și pentru activitatea de devoltarea durabilă pentru fizicienii medicali sunt necesare documentații detaliate în literatura de specialitate cu scopul de a identifica metode simple de măsurarea a dozelor de radiații, indirect, prin intermediul semnalului RES datorat radicalilor liberi induși în diferite sisteme moleculare.

In acest sens am elaborat o documentare detaliată din literatura de specialitate în scopul identificării celor mai recente preocupări științifice referitoare dozimetria radiațiilor folosind tehnica EPR (Electron Paramagnetic Resonance) cu sisteme simple și neostisitoare.

In acest document raportăm o serie de articole științifice noi, publicate în literatura de specialitate, referitoare la folosirea dozimetriei EPR cu sisteme moleculare ne-clasice. Aceste articole vor fi puse la dispoziția studenților pe canalele de comunicare on-line (platform Teams, site-ul proiectului).
Documentul este organizat în felul următor:

1. datele de identificare a articolelor (autori, titlu, anul apariției, volum, pagina de început și sfârșit/numărul articolului, adresa DOI.
2. abstractul articolului
3. concluziile articolului

Lista articolelor propuse

Articol 1

1. Tengda Zhang, Zhixin Zhao, Haiying Zhang, Hezheng Zhai, Shuzhou Ruan, Ling Jiao and Wenyi Zhang, Effects of water on fingernail electron paramagnetic resonance dosimetry, Journal of Radiation Research, 2016, 57, 460–467. doi: https://doi.org/10.1093/jrr/rrw046

Abstract

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Effects of water on fingernail electron paramagnetic resonance dosimetry

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ABSTRACT

Electron paramagnetic resonance (EPR) is a promising biodosimetric method, and fingernails are sensitive biomaterials to ionizing radiation. Therefore, kinetic energy released per unit mass (kerma) can be estimated by measuring the level of free radicals within fingernails, using EPR. However, to date this dosimetry has been deficient and insufficiently accurate. In the sampling processes and measurements, water plays a significant role. This paper discusses many effects of water on fingernail EPR dosimetry, including disturbance to EPR measurements and two different effects on the production of free radicals. Water that is unable to contact free radicals can promote the production of free radicals due to indirect ionizing effects. Therefore, varying water content within fingernails can lead to varying growth rates in the free radical concentration after irradiation—these two variables have a linear relationship, with a slope of 1.8143. Thus, EPR dosimetry needs to be adjusted according to the water content of the fingernails of an individual. When the free radicals are exposed to water, the eliminating effect will appear. Therefore, soaking fingernail pieces in water before irradiation, as many researchers have previously done, can cause estimation errors. In addition, nails need to be dehydrated before making accurately quantitative EPR measurements.

KEYWORDS: dosimetry, electron paramagnetic resonance, fingernail, ESR

Concluzii

CONCLUSION

Water either promotes or eliminates the generation of free radicals within fingernails, depending on the form of the water. Promoting the production of free radicals can be ascribed to the indirect ionizing effect. Also, different levels of water content within fingernails can lead to different growth rates in the free radical concentration induced by irradiation, and these two variables have a linear relationship with a slope of 1.8143. The eliminating effect has been known about for some time, but the chemical reaction mechanism remains unclear. This mechanism and the quantitative measuring method for the particular keratin that generates RIS need to be investigated further. One thing to note is that soaking fingernail pieces in water before irradiation can cause estimation errors. In addition, the nail samples need to be dehydrated before EPR measurements to obtain maximum accuracy.

Articol 2

2. J. Kaminska, B. Ciesielski , B. Drogoszewska, K. Emerich, K. Krefft, M. Juniewicz, Verification of radiotherapy doses by EPR dosimetry in patients' teeth, Radiation Measurements, 2016, 92, 86-92 doi: http://dx.doi.org/10.1016/j.radmeas.2016.07.005

Abstract

Verification of radiotherapy doses by EPR dosimetry in patients' teeth

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HIGHLIGHTS

- EPR signal in enamel is proportional to dose delivered *in vivo* during radiotherapy.
- The average deviation of the measured from the planned doses was −4.6%.
- The doses in enamel can be determined many years after radiotherapy.

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ABSTRACT

The aim of this work was to verify applicability of electron paramagnetic resonance (EPR) *ex vivo* dosimetry in teeth enamel for determination of doses absorbed by patients during radiotherapy with radiation fields covering head regions and to examine with what accuracy the doses predicted by radiotherapy treatment plan (RTP) can be confirmed by doses measured *ex post* by the EPR method. The doses were determined in 22 enamel samples obtained from 11 patients who, after their radiotherapy treatment underwent extraction of teeth due to medical reasons. The delivered doses were determined by measuring EPR signals in enamel samples from the extracted teeth; magnitude of these signals is proportional to concentration of stable free radicals induced by radiation in the hydroxyapatite content of enamel. The measured doses were compared with doses planned in the teeth locations by RTP systems. The relation between the measured (D_m) and the planned (D_p) doses can be described as a linear function: $D_m = s{\cdot}D_p + b$, with the slope $s = 0.93 \pm 0.03$ and the intercept $b = 0.67 \pm 1.26$. The deviations between the measured and calculated doses were in the (−12.6%, +1.9%) range with the average deviation of − 4.6%. It is concluded, than more accurate measurements, achievable when using a higher calibration dose than in the present study, are necessary to confirm or to deny the observed bias between the measured and planned doses.

Concluzii

The uncertainty of individual doses was relatively high – reaching up to about 10% of the planned dose for the high dose samples. This can partially explain the obtained relatively large deviations (from −12.6% up to +1.9%) between the measured and the planned doses. The uncertainty calculations illustrated in Fig. 5 lead to interesting and unusual conclusion that the relative accuracy of dose measurements is worse for high measured doses then for low doses. This effect can be intuitively understood realizing, that when precision of measurements is a constant fraction of the measured quantities, then their absolute uncertainties are becoming an increasing fraction of the calculated difference between the two measured quantities. Analysis of the effect of the value of D_{cal} on the uncertainties (Fig. 5, Eq. (5)) leads to the conclusion, that accuracy of the dosimetry can be significantly increased when using a higher calibration dose than the $D_{cal} = 25$ Gy used in this work. Unfortunately, due to limitations in access to the medical accelerator used daily in clinic for radiotherapy, an increase in irradiation time was not possible in the present work. For $D_{cal} = 100$ Gy or higher the accuracy would be better than 5% for doses up to 60 Gy (Fig. 5). Such accuracy level is close to general requirements in radiotherapy regarding concordance between the planned and delivered doses. Therefore the use of a high calibration dose D_{cal}, at least four times higher than the expected measured doses, should be recommended in retrospective dosimetry with the additive dose method.

The variations in radiation sensitivity of the individual enamel samples varied about 35% (with standard deviation 18%) from their average value (Fig. 6). This fact strongly confirms a need for individual calibration of radiation sensitivity of enamel in order to eliminate potential errors related to variability in its radiation sensitivity. Smaller deviations in inter-sample sensitivity were reported by Wieser et al (Wieser et al., 2001). – with standard deviations of only 5–10%, depending on sample preparation procedure. The higher scatter in sensitivity in our samples can be related to different physiological conditions of the donors' teeth – most of the teeth used in our work were extracted due to radiation necrosis of adjacent tissues, being a side effect of radiotherapy.

Any potential bias in the measured doses from sunlight-induced contributions to the measured *RIS*'es can be neglected in enamel samples coming from premolars or molars, in particular at such high doses (tens of Gy) applied here; the effect of sunlight on *RIS* in incisors (which are much more exposed to sunlight than premolars and molars) was estimated in victims of atomic bomb attacks in Japan to be below 0.5 Gy (Nakamura et al., 2006).

The results presented here showed proportionality between the planned and the measured doses, as reflected by the slope of linear relation between these two doses: $s = 0.93 \pm 0.03$. This indicates about 7% systematic deviation between the planned and measured doses. Due to uncertainties of the measured doses, this conclusion should be confirmed by measurements with a higher accuracy than reached in this study. However, it should be noticed, that a linear regression of the data taken from (Pass et al., 1998) and (Ciesielski et al., 2007) for "in field" teeth gives the respective slopes equal to 0.98 and 0.92, respectively. This several percent underestimation of the planned doses by EPR measurements rather cannot be related to any time-related effects, i.e. decay of the dosimetric signal after radiotherapy. The small negative slope $s = -0.056$ of the line in Fig. 7 with the low value of the correlation coefficient ($R^2 = 0.06$) does not confirm any *in vivo* decay in time after radiotherapy; even in contrary – it suggests long term stability in *in vivo* conditions of the radiation-induced radicals. More plausible explanation of the observed bias can be related to tissue inhomogeneities and air spaces in the oral cavity and/or possible changes in geometry of tissues during the course of radiotherapy, which were not accounted by RTP calculations. Consequently, our results, due to limits of their accuracy, can confirm only approximately a concordance between the doses calculated by RTP protocols and the actual doses delivered during radiotherapy. A similar study was recently published by Krefft et al. (Krefft et al., 2014), in which doses planned by RTP were verified by EPR measurements of bone fragments from radiotherapy patients. These reported results of EPR dosimetry performed on enamel or bone irradiated *in vivo* under the controlled and well defined exposure conditions during radiotherapy, demonstrate a potential of EPR dosimetry for *ex post* verification of doses received during radiation therapy, even years after the treatment. However, additional studies with a higher accuracy than achieved in this work are necessary to verify or to deny the observed systematic differences and, if confirmed, to explain their origin.

Articol 3

3. M. Mikou, N.Ghosne, R.ElBaydaoui, Z.Zirari, F.Kuntz, Performance characteristics of the EPR dosimetry system with table sugar in radiotherapy applications, Applied Radiation and Isotopes, 2015, 99, 1-4. doi: http://dx.doi.org/10.1016/j.apradiso.2015.02.010

Abstract

Performance characteristics of the EPR dosimetry system with table sugar in radiotherapy applications

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HIGHLIGHTS

- Monitoring and evaluation of the assigned dose in radiotherapy.
- Analysis of X-ray irradiated table sugar by using non-destructive EPR method.
- Determination of the threshold measurable dose.
- Determination of calibration curves by peak to peak and double integration methods.
- Dosimetric potentialities of sugar/EPR system in radiotherapy.

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ABSTRACT

Performance characteristics of the megavoltage photon dose measurements with EPR and table sugar were analyzed. An advantage of sugar as a dosimetric material is its tissue equivalency. The minimal detectable dose was found to be 1.5 Gy for both the 6 and 18 MV photons. The dose response curves are linear up to at least 20 Gy. The energy dependence of the dose response in the megavoltage energy range is very weak and probably statistically insignificant. Reproducibility of measurements of various doses in this range performed with the peak-to-peak and double-integral methods is reported. The method can be used in real-time dosimetry in radiation therapy.

Concluzii

4. Conclusions and outlook

Our results suggest that sugar makes it possible to measure absorbed radiation doses in the 1.5–20 Gy range with a precision better than 5%. The dose response curves are linear in this range. No significant effect of the radiation energy was observed.

Although the peak-to-peak amplitude and double integral methods lead to similar results and the former is faster, the double integration method, if used with proper baseline correction, seems to be more reliable because it takes into account absorption by all the radiation-induced species.

In perspective, it would be interesting to manufacture sugar pellets calibrated in terms of mass and volume in order to minimize uncertainties related to these two parameters. A thorough test of the response of sugar pellets in radiotherapy treatments would validate the sugar/EPR dosimetry system in radiotherapy.