A comparative study of four polymer gel dosimeters

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1. Introduction

In this study we have investigated and evaluated some dosimetric properties of polymer gel dosimeter encountered when using gels in clinical radiation therapy environment. Four different compositions of polymer gel dosimeter were manufactured (table 1).

|        | A    | B    | C    | D    |
|--------|------|------|------|------|
| gelatin| 5 %  | 5 %  | 5 %  | 5 %  |
| acrylic acid | 3 %  | 3 %  | 3 %  |      |
| methylene-bis-acrylamide | 3 %  | 3 %  | 3 %  |      |
| methacrylic acid |      |      |      | 6 %  |
| sodium hydroxide | 1 %  |      |      |      |
| potassium aluminium sulfate |      |      |      | 5 %  |
| copper sulfate |      |      |      | 8.2 \times 10^3 \text{ M} |
| ascorbic acid |      |      |      | 2.0 \times 10^{-3} \text{ M} |

Two compositions (A and D) represent widely recognized gels prepared following instructions of [1–3]. In case of MAGIC type dosimeter (D), gelatin weight fraction was decreased to 5%. During our previous research, we have experienced some substantial changes in behavior when lowering amount of sodium hydroxide and when potassium aluminum sulfate was added. Therefore another two gels were prepared (B and C). Gel dosimeters were evaluated using transversal relaxation rate $R_2$. Details of the used acquisition sequence may be found in [4], only eight echo times were used for $R_2$ calculation in this case.
The following properties have been investigated for the four gel compositions:
- dose response,
- temperature dependence of dose response,
- short and long term stability,
- behavior of gels in a region of steep dose gradient,
- and uniformity of homogeneously irradiated region.

2. Dose response (figure 1)

Dynamic range and sensitivity of a BANG type dosimeter significantly improves when an amount of sodium hydroxide is decreased. Our previous study exhibits a well-defined dependence between gel’s pH and its sensitivity (expressed by a slope of regression line in the region of linear dose response, figure 2). Also, a slight decrease in dosimeter’s background was observed when pH decreases. Adding potassium aluminum sulfate (gel C) highly improves dosimeter’s sensitivity and a span of dynamic response, still maintaining low background signal. High $R_2$ response of a non-irradiated sample is a drawback of gel D. Moreover, the level of background seems to be very dependent on concentration of dissolved oxygen.

![Figure 1. R2 response to dose for the four different gel dosimeters.](image1)

![Figure 2. Dependence of gel's sensitivity on its pH.](image2)

Gel B’s melting point is only about 25 °C and is therefore unsuitable to use in clinical praxis. An improvement can be achieved by increasing dosimeter’s pH adding sodium hydroxide. However, dose response must be compromised in this case. As our previous measurements show, gels A and C both exhibit melting point about 32 °C. Melting point differs not only with gel composition but also with temperature history of gel samples. Storing dosimeters in a fridge an entire time since their manufacture is questionable as in this case the lowest melting point was experienced for all gels.
3. Temperature dependence of dose response

Correction factors for temperature effect during MRI evaluation of gel samples were calculated following procedures described in [4]. From the four compared gels, $R_2$ response of gel C is the least sensitive to changes in temperature. At the temperature of 25 °C, $R_2$ changes by only 1% per °C (gel A: 2 % per °C, gel B: 3 % per °C, gel D: 2.6 % per °C).

4. Short and long term stability

$R_2$ was measured at different times since irradiation for samples homogeneously irradiated to doses 0, 12 and 30 Gy. The measurement was performed approximately every 30 minutes for several hours after irradiation. Additional measurements were carried out in one and two weeks after irradiation. The gels B and C perform slow kinetics of polymerization (figure 3). Approximately a 12-hour-period is needed for stabilization of $R_2$ response. Gels A and D exhibit only slight time changes of $R_2$ response.

![Figure 3. Short-term changes in $R_2$ response.](image)

5. Steep dose gradients (figure 4)

Long tubes filled with gel were partially irradiated to doses 12 and 30 Gy using one 18 MV field (dose rate 4 Gy/min at the reference depth) with one edge of the rectangular field positioned on central axis to provide the steepest dose gradient. Gradient profiles were measured during several hours after
irradiation and subsequently after another 10 and 20 days. In the short-term period, no changes in a FWHM of derivation of dose gradient profile were observed. In long-term period, an enhancement of response on the edge of the irradiated part of the gradient was observed in case of gels A and D. The profiles were compared with measurements using conventional clinical dosimeters (such as film dosimetry, ionization chamber).

6. Uniformity of homogeneously irradiated region

Axial MR images were acquired to evaluate uniformity of a response for a set of gel samples homogeneously irradiated to doses between 0 and 30 Gy and for a set of home made standards of CuSO₄ solution varying in concentration. Standard deviations and relative standard deviations of the

![Figure 4. Dose profiles of gradient region.](image)

![Figure 5. Dependence of absolute standard deviation on R₂.](image)
investigated regions were plotted as a function of dose and R₂. It was observed that standard deviation increases with R₂ and is independent on gel’s composition (figure 5). For the same R₂, standard deviation of CuSO₄ samples is approximately half the value of gel samples in investigated region of R₂ values.

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References

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