Sequential beam integration characteristics of a methacrylic acid based normoxic polymer gel dosimeter

Anna Karlsson¹, Helen Gustavsson¹², Sofie Månsson¹ and Sven ÅJ Bäck¹

Department of Medical Radiation Physics¹, Lund University,
Malmö University Hospital, Sweden
Siemens Medical Solutions², Stockholm, Sweden

1. Introduction
Polymer gel dosimetry offers great potential for volumetric measurements of dose distributions from complex radiotherapy treatment modalities [e.g., 1-3]. In order to assess the quality of a gel dosimeter to be used for radiotherapy dosimetry, a number of properties, such as dose resolution, temporal and spatial stability, beam quality dependence, dose rate dependence, and temperature dependence during manufacturing, irradiation and read out should be characterized. Recent studies have contributed to the characterization of normoxic polymer gel dosimeters [4-6]. Pronounced effects in some of the properties mentioned above have been reported when the gel composition was changed. Thus, each new gel composition has to be characterized.

Polymer gel dosimeters are considered to be dose integrating dosimetry systems [cf. 7]. The aim of this study was to investigate the dose integration properties for a methacrylic acid based normoxic polymer gel dosimeter. The effect of sequential irradiation was investigated for different fractionation schemes and varying amounts of methacrylic acid (MAA).

2. Materials and Methods

2.1. Gel preparation
In this study, three gel compositions were investigated (table 1). The mixing procedure has been described elsewhere (Gustavsson et al 2004). All gel samples were left to set in room temperature (approx. 20° C) over night.

2.2. Irradiation, magnetic resonance imaging and evaluation
All gels were irradiated using an Elekta Sli (Sweden) linear accelerator. Small (15 ml) gel-filled glass vials were used for dose response evaluation. The vials were irradiated using 18 MV photons at the depth of dose maximum, in order to ensure a homogenous absorbed dose over the sample, in a 30 x 30 x 30 cm³ water phantom. The beam was turned off for approximately 60-100 sec between two sequential beams. The dose rate at the position where the vials were irradiated was 5.1 Gy min⁻¹.
Magnetic resonance imaging was undertaken using a Siemens Symphony 1.5 T scanner (Siemens Medical Solutions, Germany). The gels were scanned using a 32-echo multiple spin echo sequence, with repetition time 4000 ms, inter echo time 10.6 ms, and voxel size 1.0 x 1.0 x 3.0 mm$^3$. Two acquisitions were averaged for each scan.

### 3. Results and Discussion

The R2 versus absorbed dose response was found to be dependent of the fractionation scheme when the total absorbed dose was divided into fractions of 0.25, 0.5, 1 and 2 Gy (figure 1a). The effect was larger when a higher total dose was given (figure 1b). When the dose per fraction was decreased the slope of the R2 versus absorbed dose response was increased (figure 2).

The slope of the response for the various fractionation schemes (figure 2) was decreased in a way resembling to the dose-rate dependence reported by De Deene et al (2006). This may indicate that the sequential beam dependence could be caused by a similar mechanism as the one responsible for the dose rate dependence. However, to analyse the cause, further investigations need to be undertaken.

For the gels with increasing concentrations of MAA, the slope of the dose response curves increased when the dose was given in 0.5 Gy fractions compared to a single fraction (figure 3a). The increase was 35, 37 and 103% for gels containing 2, 4 and 8% MAA, respectively (figure 3b). The increased slope ratios indicate dependence on the amount of MAA. Previous studies (De Deene et al 2006) show that the dose rate effect is more pronounced in a more sensitive gel, which is consistent with these results.

**Table 1.** Gel compositions.

| Residual amount – ultra pure deionised water. |
|---------------------------------------------|
| Gelatine                                    |
| Methacrylic acid                            |
| THP                                         |

| Gelatine  | 8% w/w                          |
| 2%, 4%, 8% w/w |
| 2 mM w/w     |

**Figure 1.** Gel samples (2% MAA) irradiated to absorbed doses up to 10 Gy. The total dose was divided into fractions of 0.25, 0.5, 1 and 2 Gy. The R2 versus dose response when delivering the total dose in a single fraction was included as well (a). When the total dose was delivered with sequential beams the R2 response for the total absorbed dose was increased with increased number of beams (b). The uncertainty bars correspond to the standard deviation (1 SD) in the R2 map.
Figure 3. Gel samples (2% MAA (black), 4 % MAA (grey), 8 % MAA (insert)) irradiated to absorbed doses up to 10 Gy. The data for the gel that contained 8% MAA was inserted in figure 3a in order to utilize a more suitable dynamic range for the $R^2$-values corresponding to the response of the gels that contained 2 and 4% MAA. The total dose was divided into fractions of 0.5 Gy (circles). The $R^2$ versus dose response when the total dose was delivered with a single fraction (squares) was included as well (a). Slope versus concentration of MAA for the fractionation scheme with 0.5 Gy per fraction (○) and when the total dose was delivered with a single fraction (■) (b). The uncertainty bars correspond to the standard deviation in the $R^2$ map (a) and to the standard deviation of the linear fits of the slopes (b). The linear fits to assess the slopes had correlation coefficients ($R^2$) higher than 0.994.

4. Conclusion
For the MAA based polymer gel investigated in this study the absorbed dose response was found to be dependent on the fractionation scheme. The $R^2$ versus total absorbed dose response was increased when the dose per fraction was decreased. A dependence on the concentration of MAA was also observed. Furthermore, the effect was larger when a higher total dose was given. Further
investigations need to be undertaken to investigate the effect on different gel compositions. Other combinations of monomer and gelling agent may result in more stable normoxic polymer gel dosimeters.

5. References
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