Supplemental Material: Relative dosimetry with an MR-linac: Response of ion chambers, diamond, and diode detectors for off-axis, depth dose and output factor measurements

Daniel J. O'Brien, James Dolan, Stefan Pencea, Nicholas Schupp and Gabriel O. Sawakuchi

Monte Carlo Calculation of a Farmer Chamber's Effective Point of Measurement in a Magnetic Field

Percentage depth dose and profile data was calculated using Geant4 (v9.6p04) in water and with a model PTW 30013 Farmer chamber with and without a 1.5 T magnetic field parallel with the chamber. A point source was used with the energy spectrum of an Elekta MR-linac collimated to a 10 × 10 cm^2 field defined at a distance of 143.5 cm and an source to surface distance (SSD) of 133.5 cm. The water voxels used to score dose had the same volume as the Farmer chamber to mimic any volume averaging effects. The profiles were calculated at a depth of 10 cm along the direction perpendicular to the magnetic field. The water dose was calculated at intervals of 2 mm and 1 mm for depth dose and profile calculations, respectively. For the ion chamber calculations, the profiles were calculated with intervals of 1 mm in the penumbra and near the central axis and 5 mm everywhere else and the depth dose values were calculated at intervals of 1 mm down to a depth of 2.5 cm and then at intervals of 1 cm thereafter. Statistical uncertainties were within 0.3% for the water calculations; varied with depth from 0.4% to 0.9% for the ion chamber depth dose calculations; and varied from 0.5% at the central axis to 2.6% out-of-field for the ion chamber profile calculations. All other parameters were the same as described in O'Brien et al. 2016 (Med. Phys. 43(8), 4915–4927). To determine the offset of the chamber's effective point of measurement (EPOM) from the chamber center, the χ^2 minimization technique of Kawrakow 2006 (Med. Phys. 33(6), 1829-1839) was used. This involves calculating for each depth z the ratio $D_w(z+\Delta z)/D_g(z)$ where D_w is the dose to water, D_g is the dose to the gas in the chamber's sensitive cavity, and Δz is the offset to be calculated and then minimizing χ^2 as a function of Δz to find the offset value that produces the best agreement between the water and ion chamber depth dose curves. To determine if there was also a lateral offset induced by the magnetic field, a similar technique was applied to the profile data. The results are shown in Figures S1 and S2. The magnetic field appears to reduce the vertical offset of the EPOM by approximately 50%. Meanwhile, it also induces a lateral offset of approximately the same magnitude. These results are in agreement with the measurements presented in the main paper.

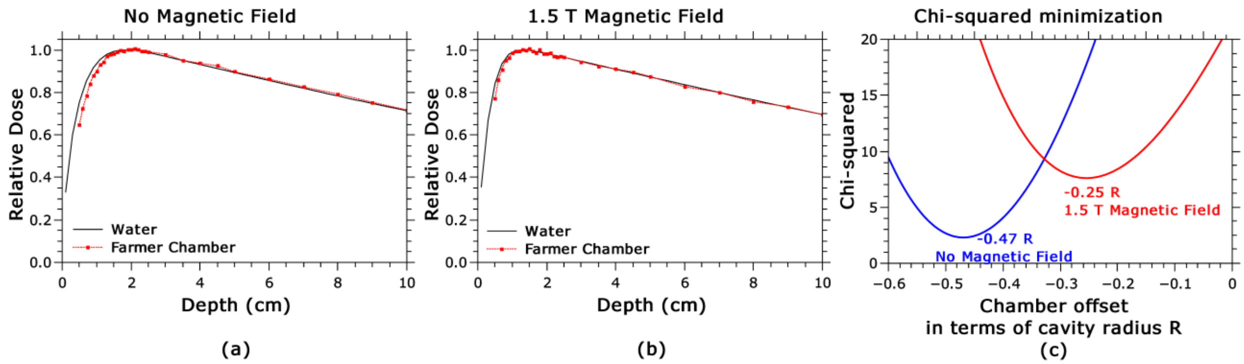

Figure S1. Vertical offset determination using the Chi-squared minimization technique. The vertical offset was reduced by 53% when the 1.5 T magnetic field was present.

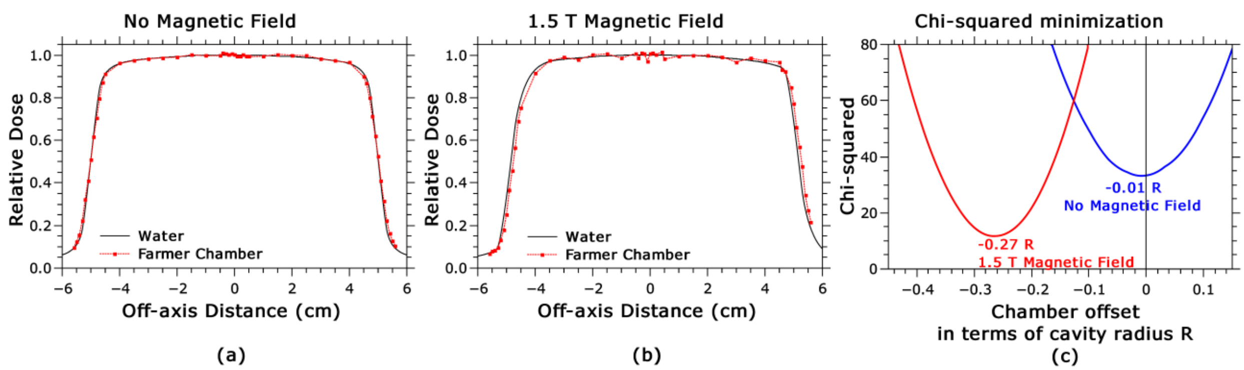

Figure S2. Lateral offset determination using the Chi-squared minimization technique. A lateral offset of 0.27 times the cavity radius (or 0.82 mm) was found when the 1.5 T magnetic field was present.