

Modelling and measuring small radiotherapy photon fields

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Background and purpose

Measuring dose distributions of small photon fields, used in Stereotactic Radiosurgery or IMRT, generates problems not encountered at larger field size [1]. This work aims to quantify these effects and suggest methods of reducing the errors associated with them.

Method

A Monte Carlo model was fitted to dosimetric data measured for large fields and used to predict small-field profiles, depth doses and output factors [2]. The MC small-field profiles and PDDs matched unshielded diode measurements but for the smallest field size, measured and predicted OF differed significantly. Possible reasons for this discrepancy were investigated using the MC model. First the influence of detector size on OF, PDD and penumbra widths was modelled. Then the variation with field size of the dose-to-water to dose-to-medium ratios for detector-sized voxels of silicon ($\rho=2.3 \text{ g/cm}^3$), diamond ($\rho=3.5 \text{ g/cm}^3$), and air in a water phantom were calculated. Finally the effect of varying the photon focal spot size (by changing the MC-modelled incident electron beam width) on predicted penumbra widths and small-field OF was determined.

Results

Changes in penumbra width, PDD and OF with detector volume have been identified for small fields. For a 0.5 cm square field, increasing the MC detector diameter from 1 to 3mm reduces the OF by $7\pm 1.5\%$ (1sd) and increases the PDD at 15 cm by $3\pm 1\%$. However this effect was not sufficient to explain the difference between predicted small-field OF and that measured with an unshielded diode.

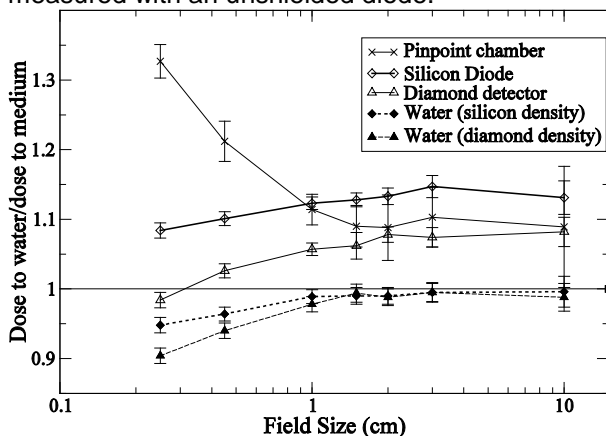


Figure 1 Ratios of dose-to-water to dose-to-medium for various detector materials at 5 cm depth at 15 MV.

The variation with field size of the silicon to water stopping power- and mass energy-absorption ratios is minimal [2]. However, the dose-to-detector to dose-to-water ratio does change significantly as field size decreases (figure 1). Similar results are obtained for voxels of water with increased density suggesting the effect is due to the density rather than atomic number of the detecting material. Even with this correction applied, the measured OF still differs significantly from the MC value.

The variation of modelled photon focal spot width is seen to have a large effect on the output factor for the smallest field, probably due to occlusion of the source by the linac jaws, without significantly affecting the OF or penumbra width of larger fields (figure 2).

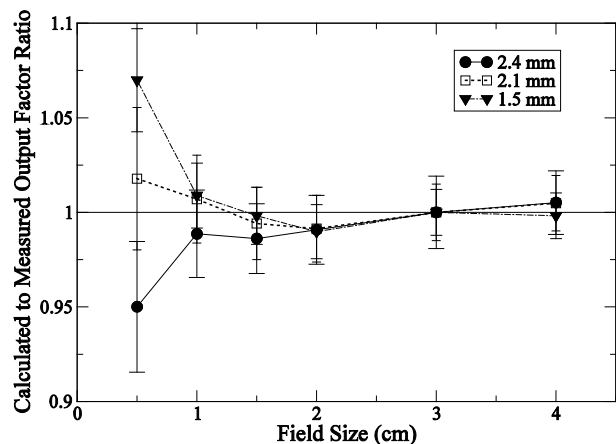


Figure 2 Ratios of MC calculated and measured OF for various modelled photon focal spot widths (FWHM). For field sizes of 1 cm and above there is no significant variation.

Conclusions

For small-field dosimetry, detector size has a significant influence on the PDD and OF; therefore the smallest detector possible should be used. All non-water materials introduce a constant scaling factor in measured dose however this is accounted for by calibrating the detector. In a similar sized field. For very small fields, the key detector property is the density as this influences the variation of response with field size. The focal spot size used in a beam model significantly affects small-field output factor and so should be chosen carefully.

References

- [1] Das IJ, Ding GX and Ahnesjö A, Small fields: Nonequilibrium radiation dosimetry. *Medical Physics*, 2008: 35: 206-215
- [2] Scott AJ, Nahum AE and Fenwick JD. Using a Monte Carlo model to predict dosimetric properties of small radiotherapy photon fields. *Medical Physics*, 2008: 35: 4671-84