Introduction /Objectives

Dose measurements in phantoms surrounding brachytherapy photon sources usually have large uncertainties due to the steep dose gradients in the vicinity of the sources and the properties of the photon spectra, changing with distance from the source. These features of the radiation field coincide with detector properties such as the volume effect and the energy-dependent response. However such measurements, although rare in clinical routine but needed for certain purposes of quality control, should be made possible by suitable dosimetry protocols, involving, e.g. positioning rules and correction factors.

A project group with the task to elaborate a formalism for dose measurements in phantoms surrounding brachytherapy sources (DIN 6803-3) has been assembled and is presently collecting theoretical approaches and information about suitable detectors and phantom materials. The intention is to design a formalism to convert the reading of a probe-type detector in a brachytherapy radiation field into absorbed dose to water, providing all necessary conversion and correction factors.

Such protocol will be formulated for small ionization chambers, but can be extended to other types of probe-type dosimetry. Other types of detectors may have advantages e.g. concerning size (volume averaging) and energy dependence of the response.

Using a standardized protocol for brachytherapy dosimetry can be of help in order to verify dose calculations by planning systems, particularly when a complex geometry is involved. The formalism should help to eliminate some of the present uncertainties and may also allow improvements in in-vivo dosimetry.

Methods

The first step of dose measurement in a water or water-equivalent phantom surrounding a photon brachytherapy source would be to measure the absorbed dose to water, \( D(r_0, \theta_0) \) under “reference conditions”, i.e. at the TG43 reference point \( r_0=1 \, \text{cm}, \theta_0=90^\circ \) and for reference conditions of influence factors such as air density and temperature:

\[
D(r_0, \theta_0) = M \cdot N \cdot k_{Q,R} \cdot k_{V}(r_0, \theta_0) \cdot k_i
\]

where:

\( M \) : reading of the detector
\( N \) : manufacturer-supplied calibration factor of the detector in a Co-60 gamma-ray beam (calibration conditions) \( k_{Q,R} \) : correction for radiation quality, e.g. \( \text{Ir-192} \) photons \( k_v \) : corrections for differences from reference conditions such as by air density temperature. \( k_i \) : correction for volume averaging and perturbation of the radiation field by the detector

For dose measurement at any other point \( r, \theta \) in the phantom an additional factor \( k_{Q,K} \) for non-reference conditions such as the different local photon spectrum is needed:

\[
D(r, \theta) = M \cdot N \cdot k_{Q,R} \cdot k_{Q,K}(r, \theta) \cdot k_i
\]

Determination of \( k_{Q,R} \) and \( k_{N,R} \) by:

- Analysis of the spectral changes with distance of the radiation field surrounding a brachytherapy source by Monte Carlo simulation and literature [1,2,3]
- Examination of the energy dependent response of a number of typical brachytherapy detectors with Monte Carlo simulations [1]
- Examination of water equivalent phantom materials with Monte Carlo calculations for their specific influence on the brachytherapy photon spectrum and on their water equivalence in terms of generating equivalent distributions of photon spectra and absorbed dose to water. [2]

So far, the calculations have only been performed for \( \text{Ir-192} \) afterloading sources. Calculations for \( \text{Co-60} \) sources are planned.

The correction for volume averaging \( k_i \) must still be examined. The strategy is to find detectors with a small volume averaging effect, which requires a small sensitive volume.

Conclusions

A simple description of the energy dependence of a detector in the vicinity of a brachytherapy source was found by defining an energy correction factor \( k_i \) for brachytherapy in the same manner as in existing dosimetry protocols. The factor can be calculated as a polynomial of the mean energy of the spectral fluence, \( E_p \), or of the distance from the source.

The introduction of an energy correction factor \( k_{Q,R} \) for brachytherapy sources may allow more systematic and comparable dose measurements. Since \( k_i \) is defined in relation to the TG43 reference point, the contributions can, in principle, be verified or even determined by measurement in a water phantom and comparison with dose distributions calculated using the TG43 dosimetry formalism. The corrections have been determined for high energy afterloading sources. In principle, the same formalism can also be used for low energy sources such as seeds. However, here volume averaging and perturbation of the radiation field will probably be more difficult to describe.

References

