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Purpose or Objective

kV radiotherapy continues to be an important modality in modern radiotherapy, but has received less research attention in recent years. There remains a challenge to accurately calculate and verify treatment dose distributions for clinical sites with significant surface irregularity or where the treated region contains inhomogeneities, e.g. nose and ear. The accuracy of current treatment calculations has a significant level of uncertainty [1, 2]. The objective of this work was to characterise two novel detectors, micro-silica bead TLDs and Gafchromic EBT3 film, for in-vivo measurements for kV treatments, and to compare measured doses with conventional treatment calculations.

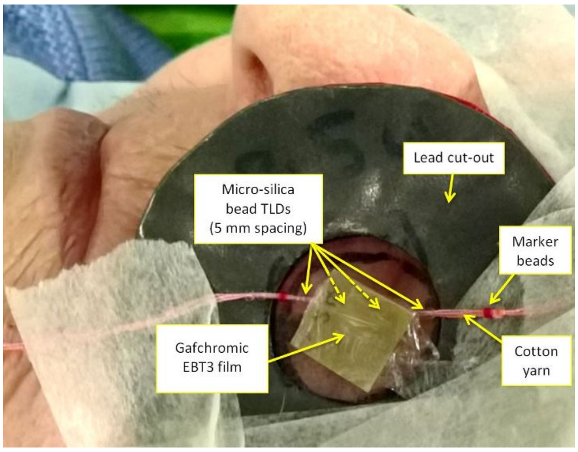
[1. Currie (2007) Australas Phys Eng Sci Med, 2. Chow (2012) Rep Pract Oncol Radiother.]

Material and Methods

Micro-silica bead TLDs (1 mm diam.) and Gafchromic EBT3 film were calibrated against an NPL traceably calibrated ionisation chamber using an Xstrahl D3300 kV radiotherapy treatment unit. Energy response was evaluated over 70 to 250 kV and compared to 6 MV, useable dose range was evaluated from 0 to 25 Gy, and uncertainty budgets determined. Silica beads were cleaned, annealed, and TL response individually calibrated. EBT3 film was used with triple-channel dosimetry via FilmQAPro® with procedures to reduce uncertainties. Commissioning tests were undertaken in standard conditions using Solid Water blocks and in simulated clinical treatment condition using a custom made 'wax face with nose' phantom. Pilot in vivo measurements were made for a consecutive series of eight clinical patient treatments, including cheek, ear, nose and rib sites, over 70 to 250 kV, and 4 to 18 Gy. Results for the two dosimetry systems were compared to conventional treatment planning calculations.

Results

Energy response varied by 460% for beads and 9% for film, from 70 kV to 6 MV, necessitating energy-specific calibration. Both dosimeters were useable up to 25 Gy. Standard uncertainty was 3.1% for beads, 2.1% for film. The figure shows typical film and bead positions within the lead cut-out of a kV treatment to the cheek. The table provides calculated and measured doses. Average deviation over 6 patients was -1.3% for beads, -0.9% for film. 3 patients had larger deviations; See table note 1: tumour sitting over the maxillary sinus may reduce dose. Note 2: beads placed along surface of tumour into ear, most distal bead received dose -17.5% from prescription, doctor made compensation. Note 3: Increased uncertainty due to curved surface, film required offset to corner as patient sensitive to contact. Note 4: Uncertainty increased due to large respiratory motion at treatment site.



Dose per #, energy and site			EBT3 Film		Micro-Silica bead		Notes (see text)
			Measured dose, Gy, (±2.1%, k=1)	% diff. to calc.	Measured dose, Gy, (±3.1%, k=1)	% diff. to calc.	
10 Gy,	100 kV,	Cheek	9.176	-8.2	9.090	-9.1	1.
4 Gy,	250 kV,	Ear	3.998	0.0	4.030	0.7	2.
4 Gy,	70 kV,	Nose	4.015	0.4	3.992	-0.2	
7.5 Gy,	100 kV,	Cheek	7.253	-3.3	7.240	-3.5	
10 Gy,	140 kV,	Ear	10.154	1.5	10.053	0.5	
8 Gy,	250 kV,	Rib	7.053	-8.3	7.528	-5.9	3.
18 Gy,	100 kV,	Ear	17.471	-2.9	17.308	-3.8	
4 Gy,	250 kV,	Rib	3.861	-3.5	3.721	-7.0	4.

Conclusion

Both micro-silica bead TLDs and EBT3 film were characterised as suitable for in vivo dosimetry in kV radiotherapy, providing assurance of delivered doses. Film is simpler to prepare, use and read. A line of beads allows conformation to irregular anatomy across the field. A clinical service is now available to verify dose delivery in complex clinical sites.

PO-0791 Determination of water mean ionization potential for Geant4 simulations of therapeutical ion beams

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Purpose or Objective

To characterize protons and ion beams to determine the mean ionization potential (I-value) of water to be used in Monte Carlo simulations with the Geant4 Monte Carlo toolkit at energies of interest in particle therapy. The magnitude of this parameter has a strong influence on the Bragg Peak spatial position which, to our knowledge, is a key factor for treatment planning.

Material and Methods

The energy deposition distributions with respect to depth in water were obtained using an experimental setup (figure 1) which consists in a water tank, which thickness can be varied with micrometric accuracy, and two ionization chambers (ICs), the first one placed downstream the beam exit window (IC1) and the second one just behind the water tank (IC2). The mean energy deposition relative to the mean energy deposition at the entrance as function of depth in water were obtained from the ratio between the ionization produced in IC2 with respect to that of IC1. These measurements were carried out for various ion species covering a range in water between 5 and 28 cm, approximately. The absolute depth in water was determined with an estimated uncertainty of 0.2 mm.

Our Geant4 simulations were done using an ideal geometry (figure 2) composed by a water tank containing cylindrical scoring volumes, with a radius of 28 mm (actual radius of the ICs) and a thickness of 50 microns (similar to the water equivalent thickness of the ICs), to tally the energy deposition.

For the simulation of each particular beam the energy spread was adjusted by fitting the width of the experimental distal fall-off prior determining the optimum I-value by matching our calculated 82% distal depth with the experimental one.

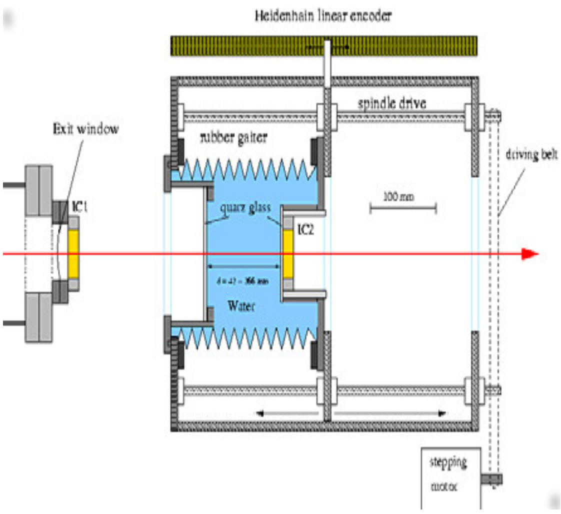

Figure 1. Experimental setup for mean energy deposition in water measurement.

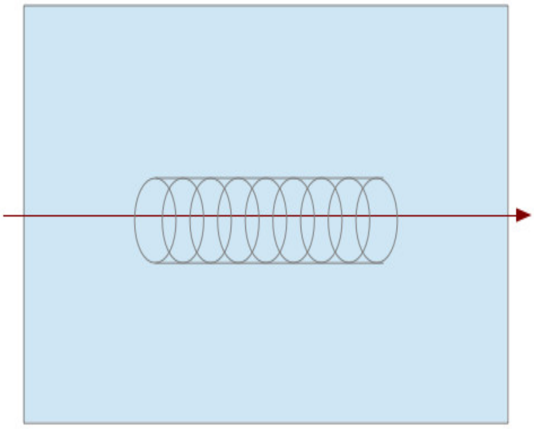

Figure 2. Ideal geometry construct in the Geant4 simulation.

Results

Our calculations give an optimal I-value of 79 eV for protons, whereas for heavier ions varies from 75 eV to 80 eV. In some cases it was found a dependence of the optimal I-value with respect to the beam energy which is being subject of further work.

Conclusion

We have calculated the energy deposition distribution as function of the depth in water for proton and ion beams. Our calculations were compared with experimental measurements in order to obtain an overall optimal I-value for simulations with the Geant4 toolkit at therapeutical energies. The values obtained varies from 75 to 80 eV, showing dependences with the particle type and energy of the beam. In fact this variation on the I-value produces a spatial translation of the Bragg Peak in the Geant4 simulation depending on the beam species and energy.

PO-0792 Monte-Carlo calculated energy deposition and nanodosimetric quantities around a gold nanoparticle

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Purpose or Objective

Interdisciplinary research on the local DNA damage after irradiation in the presence of high-Z nanomaterials, e.g. gold nanoparticles (GNP), is being performed worldwide to investigate their application for radiation imaging and therapy. An irradiation of GNP by photons leads to an enhanced secondary electron (SE) yield due to the high photoabsorption of gold. The low-energy SE are absorbed within nanometers around the GNP, thus leading to a higher ionization density and therefore, to an enhanced DNA damage in the surrounding cells. From the physical point of view, the ionization density can be related to DNA lesions via nanodosimetric quantities, such as the ionization cluster-size (ICS) distribution. The purpose of this work is to investigate this correlation by means of Monte-Carlo simulations.

Material and Methods

The energy deposition and nanodosimetric quantities in water around a single GNP were calculated by means of Geant4 simulations. The related enhancement factors were determined with respect to a water-only environment. The creation and transport of SE inside GNP of different sizes after initial irradiations with mono-energetic kV-photon sources and with three clinical spectra were modeled. The radial energy deposition, the spectrum of the kinetic energy, and the polar angle of the SE were calculated in water shells around the NP. These results were then used as input for the initial state of electrons that were transported through a DNA array of 2250 DNA cylinders, corresponding to one convolution of the DNA. For each cylinder, the ICS and the probability for inducing DNA damage, e.g. double-strand breaks (DSB), was determined. Simulations were repeated without the GNP to determine the enhancement factors for the energy deposition and the DNA-damage probability.

Results

The enhanced SE yield contributes to the increasing energy deposition in the vicinity of the GNP. For example, for a GNP with a diameter of 30 nm and an incident photon energy of 10 keV the dose enhancement is largest near the surface (R_D ≈1300) but rapidly decreases to a factor of about 30 at a distance of 300 nm. This enhancement shows a maximum for the 50 kVp therapeutic spectrum (about 190 at 300 nm) and decreases for higher energetic sources. For the 12 nm GNP, the enhancement at 300 nm is lower than for the 30 nm GNP by a factor of about 2.5 for all investigated photon spectra. The mean enhancement for the probability of inducing a DSB at 35 nm is approximately 2.4 for 10 keV photons and 12 nm GNP, even though R_D ≈50.

Conclusion

The enhancement of the energy deposition, obtained in this work, is in good agreement with literature data. A comparison of the calculated probabilities for a DSB with literature data about dose enhancement in vitro show that nanodosimetric quantities are more appropriate than absorbed dose for investigating the correlation between physical effects and DNA damage in cells.

PO-0793 Absorbed dose distributions of ruthenium ophthalmic plaques measured in water with radiochromic film

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Purpose or Objective

Brachytherapy with beta-emitting ^{106}Ru/^{106}Rh plaques offers good outcomes for small-to-medium melanomas and retinoblastomas. The measurement of the produced dose distributions is challenging due to the small range of the emitted beta particles and the steep dose gradients involved. Although radiochromic film is a suitable detector for beta dosimetry (high spatial resolution, self-developing, near tissue equivalent, a very thin detection layer and relatively low energy dependence), few publications report measurement data of ^{106}Ru/^{106}Rh