Generation of 3D Dosimetric Reference Datasets Using Model-Based Dose Calculations for COMS Eye Plaque Brachytherapy

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INTRODUCTION

- Eye plaque brachytherapy is one of the most common and effective treatments for ocular melanoma.
- The traditional TG-43 dose calculation algorithm calculates dose distributions using sources in water, ignoring any differences in tissue or source/applicator materials from water or patient-specific geometries.
- This is especially important in eye plaque brachytherapy where the high-Z materials of the plaque and the presence of the insert have been shown to have large effects on dose[1-3].
- Model-base dose calculation algorithms (MBDCAs) can take these inhomogeneities and geometries into account to calculate more accurate dose distributions.

AIM

- In this work we systematically develop a suite of test cases and reference datasets that may be used for validating MBDCA dose calculations for a ^{125}I eye plaque treatment, illustrated in Fig. 1.

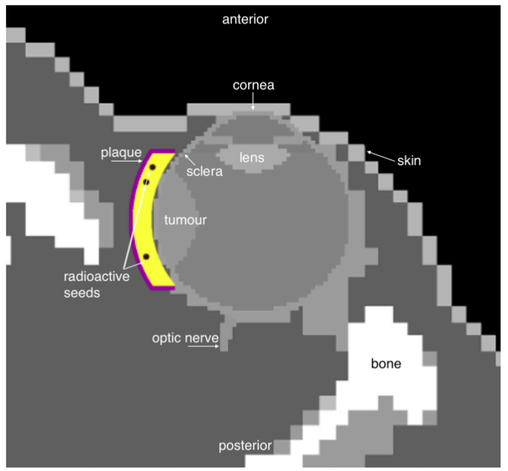

Fig. 1: Visualization of a computer-simulated eye plaque brachytherapy treatment (courtesy of Lesperance *et al.*[4]).

METHODS

- Dose calculations were performed using four Monte Carlo (MC) codes (egs_brachy (EGSnrc), ALGEBRA (GEANT4), MCNP6, and Penelope2014)
- Agreement between the codes was evaluated by comparing the results from various test cases, including air kerma (test case 1) and dose to water (test case 2) for a single seed, 13 seeds in water and positioned as in the 16 mm COMS eye plaque (test case 3, shown in Fig. 2(a)), and finally the full COMS plaque loaded with 13 seeds in a water phantom (test case 4, shown in Fig. 2(b)).
- To compare results for test cases 3 and 4, the local percentage dose difference was used, given by:

$$\%\Delta D_{local} = \frac{D(r) - D_{ref}(r)}{D_{ref}(r)} \times 100\% \qquad (1)$$

where $D(r)$ is the dose to the voxel at r from the MC/TPS being compared, and $D_{ref}(r)$ is the reference dose at r in the same voxel, here taken to be that calculated using egs_brachy.

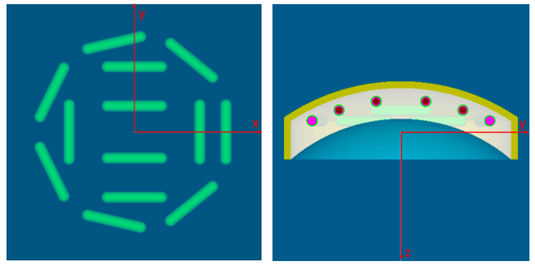

Fig. 2: (a) Positions of 13 seeds without the plaque, viewed in the x-y plane. (b) Plaque cross-section in the y-z plane. The insert has been made semi-transparent so the back seeds can be seen.

RESULTS

- All air kerma results (test case 1) were within 0.1%, with the exception of Penelope which differed by 3% (Table 1). These variations are due to the physical models used for low-energy (below 100 keV) cross sections in Penelope.
- For a single seed in water (test case 2), ALGEBRA and MCNP were within 1% and Penelope was within 2% of egs_brachy (Fig. 3 (a) and (b)).
- For TG-43 style simulations (test case 3), comparing local percentage dose differences across the scoring volume, ALGEBRA was 0.6% higher, MCNP was 1.1% lower, and Penelope was 1.0% higher than egs_brachy (Fig. 4 (a)).
- For simulations of the fully-modelled eye plaque (test case 4), comparing local percentage dose differences across the scoring volume, ALGEBRA was 1.2% lower, MCNP was 1.1% lower, and Penelope was 1.0% higher than egs_brachy (Fig. 4 (b)). Variations in the percentage dose differences were much larger when the plaque was fully modelled than when simulating a water environment.

Table 1: Air kerma values as calculated by each MC code (test case 1). Calculated using a simulated WAFAC geometry as in Taylor *et al.*[5].

code	air kerma [Gy*cm²/history]	Statistical uncertainty (k=1) [%]	ratio to egs_brachy
egs_brachy	3.7079E-14	0.027	1.0000
ALGEBRA	3.7131E-14	0.017	1.0014
MCNP5	3.7130E-14	0.030	1.0014
MCNP6	3.7131E-14	0.004	1.0014
Pen2014	3.6064E-14	0.024	0.9726

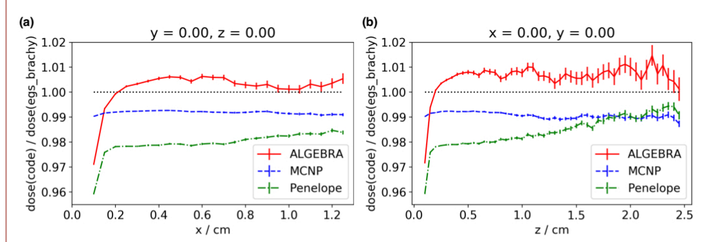

Fig. 3: (a) x-axis and (b) z-axis dose ratios for a single seed in water.

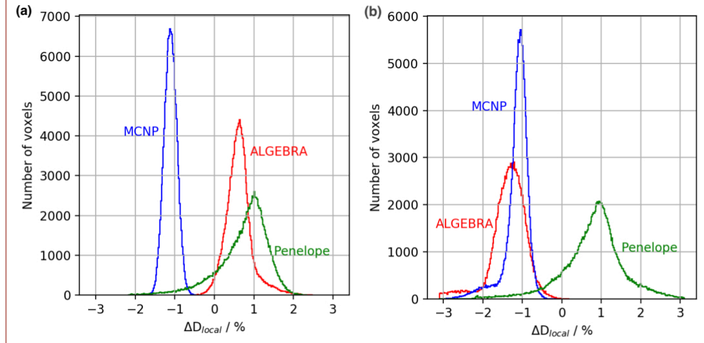

Fig. 4: Histograms of local percentage dose differences for (a) TG-43 simulations and (b) full plaque in water simulations. ΔD_{local} as calculated using Eq. 1.

CONCLUSIONS AND FUTURE WORK

- The MC codes studied exhibited agreement within 2% for these test cases.
- Next steps include simulations of the plaque in a realistic eye phantom as well as comparisons with the OncentraBrachy/ACE commercial treatment planning system.

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