Development of test cases for comparisons of model-based dose calculations in low-energy brachytherapy

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AIM

To outline a systematic framework for developing low-energy brachytherapy test cases to assist in comparing and benchmarking model-based dose calculation algorithms (MBDCAs) and implement it for the case of eye plaque brachytherapy

INTRODUCTION

- Brachytherapy dose distributions are calculated by summing the contributions from single seeds in a large water phantom (TG-43 formalism)
- TG-186 recommends adoption of MBDCAs which can account for patient geometry and tissue composition, source and applicator materials, radiation scatter, and more
- Low-energy brachytherapy is particularly sensitive to these factors due to the dominance of photoelectric interactions and their sensitivity to material cross-sections

METHODS

- Dose calculations were performed using four Monte Carlo (MC) codes for an eye plaque brachytherapy scenario
- Test cases were developed following the framework outlined in Fig. 1, progressing from simple to complex
- Local percentage dose difference was used to compare results:

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

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

Single seed in water → Superposed seeds in water (TG-43) → Seeds in water with interseed effects → Seeds in applicator(s) in water → Seeds in applicator(s) in realistic phantom

FIG 1. Framework for development of test cases

EYE PLAQUE TEST CASES

1) Single seed in water
2) Superposed seeds in water positioned as they would be in the plaque (TG-43)
3) Same as 2 but with interseed attenuation effects included
4) Seeds in water with full plaque and insert
5) Full plaque and insert in realistic eye phantom

RESULTS & DISCUSSION

- Local % dose difference was within ~2.5%
- Agreement was best for Test Case 1 and disagreement increased as the eye plaque and heterogeneous eye media were introduced
- Differences seen in simpler test cases can be used to explain differences seen in more complex ones – in Fig. 2, the single seed dose distribution (Test Case 1) can be used to explain the dose distributions in the more complex test cases
- Progression of test cases allows for troubleshooting and disentangling of user errors from fundamental differences between MBDCAs
- Although this work focused on ^{125}I eye plaque brachytherapy, the framework can readily be extended to other treatment sources and sites
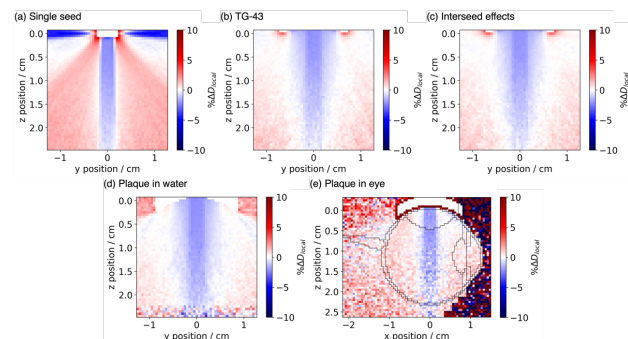

FIG 2. Local percent dose differences ($\%\Delta D_{local}$) as a function of position in the yz-plane for Penelope relative to egs_brachy for the five test cases outlined in this work

CONCLUSIONS

- Test cases for eye plaque brachytherapy were established and four MC codes were compared
- The framework established here provides a starting point for comparisons and can be extended to other applications where published benchmarked data are lacking

ACKNOWLEDGEMENTS

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